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FOREWORD

Cotton is one of the most ancient and very important commercial fibre crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It provides employment to about 70 million people and contributes nearly 75 per cent of total raw material to the textile industry in India. It is the back bone of the flourishing textile industry in India. Globally cotton is facing challenges that not only affect sustainability of production but also competitiveness with artificial fibres in the textile industry. The dawn of new millennium is witnessing changes in cultivar preferences, plant protection strategies, fibre quality requirements, displacement of cotton area etc.

India holds the unique distinction of being the only country in the world that grows all the four cultivated species of cotton and their hybrids in the vast diverse agro climatic situation prevailing across the length and breadth of the country. It is cultivated in tropical and sub tropical regions of more than 100 countries. Cotton is grown in the country in different holdings with varied planting dates, soil and water conditions largely under rainfed situation. Sustainability of production, requisite quality standards and rising cost of cultivation, pest management and environmental implications, defective irrigation practices, unstable production and widespread complaints on deterioration of fibre quality are some of the serious challenges for the scientists, developmental department staff, field functionaries and the cotton grower. To achieve this, scientists worldwide are working to meet serious scientific challenges.

Cotton in 2002 on commercial scale marks the beginning of transgenic era in the country. The problems and prospects of *Bt* cotton in the country need to be put in proper perspective. Million of people depend on cotton cultivation, trade transporation, ginning and processing for their livelihood. India is the second largest producer of cotton in the world, next to China only. However, new emerging threats in term of biotic and abiotic factors are to be understood properly and effective strategies need to be put in proper prospective. Climate change has become a major national issue as well as of global concern and such changes will affect cotton productivity and environment. Therefore, the crop scientists have a crucial and pivotal role to play in solving the problems so as to benefit the poor peasantry.

With the continued advances in plant breeding, plant genome, genetic engineering and biotechnology research, improved seed have to be evolved for reaping the untapped yield potential. Good quality seed acts as a catalyst for realizing the potential of all other agriculture inputs. Continuous efforts are required to make use of new technology for efficient crop improvement and management.

The papers appearing in this proceeding reflects the achievements made by scientists to attain higher sustainable production and this proceeding will be useful to all the stalkholders *viz.*, researchers, students, developmental department officers, planners and cotton farmers.

Sd/-
D. P. Biradar
President, Cotton Research and Development Association
CCS Haryana Agricultural University, Hisar and
Honourable Vice-Chancellor
University of Agricultural Sciences, Dharwad

Place : Dharwad

Dated : 2-3-2016

PREFACE

Cotton is an important fibre crop of India and the world as well. Indian farmers produce cotton ranging from coarse and shortest to finest and the longest fibre for all counts of spinning. There is hardly any scope of further expansion of area under cotton which calls for more attention towards improvement in productivity through conventional and unconventional approaches. The decreasing production and higher cost of production are thus, becoming a serious threat to cotton cultivation. The point of immediate concern, is to increase production by saving it from the onslaught of newly emerging pest complex.

Climate Change has become a major national issue as well as of global concern. New projections show that climate change and its consequences *i. e.* increased heat waves, melting glaciers, rise in sea level, change in temperature, ultra violet radiations, increasing carbon dioxide and other gases, depletion of nutrients in soil, erratic and scanty rainfall, declining water resources, changing pests diseases scenario will affect every aspect of life. Such changes will affect cotton productivity and environment.

Cotton is one of the most ancient and very important commercial fibre crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It is cultivated in tropical and sub tropical regions of more than 100 countries. It is the back bone of the flourishing textile industry in India. Millions of people depend on cotton cultivation, trade, transportation, ginning and processing for their livelihood. India is the only country in the world growing all the four cultivated species of cotton alongwith their hybrid combinations.

Although India ranks first in area, its productivity is lowest among major cotton growing countries. The concerted research efforts in crop improvement and development of location specific crop production and protection technologies have increased cotton production. Presently, India is the second largest producer of cotton in the world, next to China only. Crop scientists have a crucial and pivotal role to play in solving the problems so as to benefit the poor peasantry.

The research papers included in this proceeding are related to **"Crop Improvement, Biotechnology and Post Harvest Technology", "Crop Production, Mechanization and Economic Development" and "Crop Protection and Biosafety"** which were the theme areas of the symposium. Present compilation on **"Future Technologies : Indian Cotton in the Next Decade"** is a compendium of holistic advancements and other relevant information related to cotton covering different disciplines. We hope the information contained in this proceeding will be useful to all the stakeholders *viz.,* researchers, students, developmental officers, planners and farmers. All these manuscripts have been pre reviewed by eminent scientists of the respective disciplines/fields before publishing in this proceedings. We are thankful to the authors of individual papers for their contribution, time and diligence without which this volume would not have been possible. **We are also thankful to the Chief General Manager, National Bank for Agriculture and Rural Development (NABARD), Hyderabad for providing financial assistance for printing of the Proceedings.**

We deem it a rare privilege to place on record our sincere gratitude to Dr. D. P. Biradar, President, CRDA for his valuable guidance and directions in the general functioning of CRDA and the National Symposium in particular. We take this opportunity to thank all concerned and hope the proceedings will serves the purpose of cotton research for furthering the cause of cotton farmers.

Editors
Dr. R. S. Sangwan
Dr. M. S. Chauhan
Dr. Shiwani Mandhania
Dr. Omender Sangwan
Dr. Somveer Nimbal
Dr. S. R. Pundir
Dr. Neha Wadhwa
Dr. Ashish Jain

Place : CCS HAU, Hisar

Dated : 2-1-2013

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Proceedings of "Future Technologies : Indian Cotton in the Next Decade"

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LEAD PAPERS

1

Prospectus of *Bt* cotton in Haryana

S. S. SIWACH, R. S. SANGWAN AND S. NIMBAL
CCS Haryana Agricultural University, Hisar - 125 004
E-mail : snimbal@gmail.com

Cotton is the most important commercial crop of India It provides employment to millions of people in various activities such as cultivation, seed production, marketing and industrial utilization. Cotton plays an important role in Indian economy in spite of severe competition from synthetics fibre in recent year. *Gossypium* includes 50 species, four of which are cultivated, 44 are wild diploids and two are wild tetraploid (Percival and Kohel, 1990). Out of the four cultivated species, *Gossypium hirsutum* L. and *Gossypium barbadense* L. commonly called as new world cottons are tetraploid (2n = 4x = 52), whereas, *Gossypium herbaceum* L. and *Gossypium arboreum* L. are diploids (2n = 2x = 26) and are commonly called as old world cottons.

Major cotton growing are China, India, United States, Pakistan, Brazil, Turkey, Australia etc. More than 90 per area of cotton is under *G. hirsutum*. Cotton crop suffers heavy losses (about 58%) in seed cotton yield mainly due to insects in North India. As this crop is attacked by more than 230 species of insects all over the world, however 10 –15 insects are considered important and six insects cause major yield losses (Ridgeway, 1984). The damage due to sucking pests is about 18.5 per cent and bollworm contribution is 30.3 per cent.

Cotton insects are divided into following two groups.

a. **Sucking pests**: - jassids, aphids, thrips, whitefly and leaf roller.

b. **Tissue feeders**: - American bollworm, pink bollworm, spotted bollworm, tobacco cutworm, stem weevil, ash weevil and red cotton bug.

Extent and nature of damage of bollworms

Bollworms: Spotted bollworms, pink bollworm and American bollworm damage the fruiting bodies and are known as the important bollworm pests of cotton. These bollworms cause reduction in yield and quality of seed cotton.

a. **Spotted bollworms (*Earias* spp):** *Earias insulana* and *E. vittella* are the two important species of spotted bollworms which damage cotton during vegetative as well as reproductive phases of the crop. Adults of *E. insulana* dominate over *E. vittella* in the drier parts of cotton growing areas. The bud infestation results in the flaring and shedding of buds. This pest adversely affects both yield and quality of cotton.

b. **Pink bollworm (*Pectinophora gossypiella*) :** The larva is creamy in first instars, white in the second, watery in the third and pink with dark brown head in the last instars. It feeds on buds, flowers and bolls. Flower parts and the developing seeds are the main food of the larvae. This pest causes quantitative as well as qualitative loss of yield, seed and lint.

c. **American bollworm (*Helicoverpa armigera*):** It is the most important pest of cotton. Under favorable weather conditions during 2001-2002 crop season the insect caused almost failure of the crop. However, under normal infestation conditions it can cause 20-40 per cent reduction in yield, in spite of usual pesticide use.

The boll worm complex *i.e.* pink boll worms, spotted boll worms and American boll worms resulted in heavy losses to Cotton crop and the crop could not be protected against these pests inspite of 8-10 sprays. In India *Bt* cotton was introduced to manage the bollworms particularly *American* boll worm as this pest developed resistance to insecticides and threatened the cultivation of cotton. In India *Bt* Cotton cultivation started in the year 2003 with the introduction of Bollgard I (Mon 531 cry IAC), after that Bollgard II (Mon 15985-Cry 1 Ac and Cry 2 A6) was released for cultivation in 2006, JK Agri genetics developed "Event I " and Nath Seeds GFM event (fusion gene-cry 1 Ac/cry 1 Ab). Since introduction more than 1000 *Bt* Cotton hybrids have been approved for cultivation based on these four events. During almost a decade after their release *Bt* gene provide effective control against boll worms complex during the complete crop duration and no report of emergence of bollworms as serious pests was observed.

Effects of *Bt* cotton

- A sudden rise in the hybrid cotton acreage.
- A phenomenal increase in the production and productivity of the country.
- Change in the farmers preferences for agronomic traits after introduction of *Bt*
- Significant reduction in pesticide usage for bollworms after introduction of the technology.
- A phenomenal shift in cultivation of *hirsutum* in the country after introduction of *Bt* technology and *arboreum* are almost on the verge of extinction.
- A significant shift in fibre class in the country. Shortage of short and medium staple cotton.
- More preference to big boll hybrids in the country after introduction of *Bt* technology.

Problems: Some problems have became more prevalent since the cultivation of *Bt* Cotton hybrids namely

- Sudden wilting of plants
- Increased damage of sucking pests particularly whitefly
- Threat of minor pests of cotton like mealy bug, myrid bug, aphids and thrips to emerge into major pests
- Resistance to *Bt* gene
- Low yield potential and narrow adaptability
- Improvement of fibre quality to meet the industrial needs

Biotechnological applications

- First generation products:
  (Towards reducing input cost)
  Bt cotton herbicide tolerance
- Second generation products
  (Improvement of output traits like fibre quality and abiotic stress)
  - Leaf curl virus disease resistance
  - Gene pyramiding
  - Transferring fibre quality genes

However, in spite of more than 90 per cent area under *Bt* Cotton hybrids and effective control of boll worms, the yields are declining for that attention is required.

1. Ban on use of illegal *Bt* Cotton hybrids.
2. Screening of *Bt* Cotton hybrids suitable for different agro climatic conditions.
3. Sowing of refugia to harness the advantages of *Bt* Cotton technology for longer period.

Solution : Only genotypes with proven yield advantage, adaptability and proven fibre quality should be encouraged to make Indian cotton cost competitive, quality worthy and comparable with the international cotton.

Upcoming challenges

1. Changing weather pattern
2. Appearance of new pests and resurgence of existing diseases on the crop
3. Resistance management
4. To produce more from less for more
5. Hybrid seed production
6. Meeting industry needs

The cultivation of cotton has become costly affairs due to pest menace. Efforts on breeding for resistance or tolerance to insects in cotton were made during mid 1980's and early 1990's, but all such conventional efforts never resulted into a perfect cultivar which exhibited resistance to bollworm. Mean while the introduction of new engineering of biological molecules by manipulating the genetic makeup opened the new era for development of genetically modified plants. Transgenic cotton with resistance to lepidopteran insects has been released for cultivation in India in 2002. It has been observed that in a short span of period, there has been a remarkable adoption of this technology in India and it covered about 95 per cent of the total area under cotton. During this period, the yields and overall production has increased and India continued to maintain the largest area under cotton cultivation and second largest producer of cotton next to China with 34 per cent of world area and 21 per cent of world production, as a results became a net exporter of cotton from a being a net importer.

More than 300 *Bt* cotton hybrids has been recommended for North India of different seed compaies and each seed company make efforts to capture maximum share in seed market and farmers became in confusing state regarding the choice of proper hybrid for cultivation. Keeping in view following study was undertaken

Since 2009 every year around 50 most promising *Bt* cotton hybrids of different seed companies along with non *Bt* varieties and hybrids released from CCS Haryana agricultural University were planted and evaluated for seed cotton yield, earliness, insect –pest and disease data along with non *Bt* hybrids and varieties. The performances of these were sent to Department of Agriculture, Government of Haryana for their recommendation of most promising and de

Table 1. Performance of *Bt* cotton hybrids during 2010 and 2011 tested at CCS HAU, Hisar

Name of the hybrid/ variety	Seed cotton yield (kg/ha)			Ranking
	2010	2011	Average	
Pancham BG II	3436	3215	3326	1
Ankur 3028 BG II	3560	3009	3284	2
JK 1050 (JK Seeds)	3416	3138	3277	3
VICH 310 (Vikram Seeds)	3580	2803	3192	4
MRC 7017 (MAHYCO Seeds)	2922	3318	3120	5
MRC 7361 (MAHYCO Seeds)	2695	3524	3110	6
H 1226 Non *Bt* (Check variety)	3148	2855	3002	7
VICH 308 (Vikram Seeds)	2695	3 215	2955	9
RCH 605 BG II (Rasi Seeds)	2531	3241	2886	10
RCH 134 BG I (Rasi Seeds)	2263	2495	2379	Check
RCH 134 BG II (Rasi Seeds)	2963	2803	2883	Check
Bio 6488 BG I (Bio Seeds)	3086	2341	2714	Check
Bio 6488 BG II (Bio Seeds)	2963	2469	2716	Check

notification of least performing hybrids were discussed. Status of different *Bt* cotton hybrids in different years with respect to seed cotton yield were described along with their fibre quality and reaction to biotic stresses.

Seed cotton yield Two pickings were done in this experiment. First picking was done on 21.10.2012 i.e. 155 days after sowing and second picking on 19.11.2012 i.e. 184 days after sowing. On the basis of total kapas picked after second picking, the highest yield was recorded in KSCH 204 BG II (3340 kg/ha) followed by KSCH 211 BG II (3205 kg/ha). The lowest yield was recorded in the *Bt* hybrid PRCH711 BG II (58 kg/ha).

Boll weight: Maximum boll weight was recorded in Ankur 3228 BG II (4.96 g) followed by NBC 51 BG II (4.83 g). The lowest boll weight among the non *Bt* variety was recorded H 1226 (3.02g)

Ginning outturn : The ginning out turn ranged from 27.5 per cent (Ankur Jai BG II) to 35.3 per cent (Vardan BG II). In general *Bt* hybrids have less ginning out turn.

Fiber quality: The fiber of the all the *Bt* Cotton hybrids was sent for testing to CIRCOT (ICAR) laboratory for the testing of 2.5 per cent span length, Uniformity ratio, Micronaire value for fineness of the fiber and fiber strength.

2.5 per cent span length: The maximum 2.5 per cent span length was recorded in the hybrid Ankur Jai BG II (34.7mm) followed by Ankur 3228 BG II (34.1mm), NCS 459 BG II (33.4 mm), Western Nirogi 151 BG II (33.3mm). The minimum was observed in the non *Bt* check variety H 1226 (25.5mm) however among the *Bt* hybrids the lowest was recorded in the hybrids SP 7007 BGII and RCH 653 BG II 27 mm each.

Uniformity ratio: It was maximum in the *Bt* hybrids Kuber BG II (54%) followed by NBC 51 BG II and Vardan BG II (53% each). Whereas, it was lowest in the *Bt* hybrid MRC 7017 BG II (44%).

Micronaire value: Fineness of the fiber is measured by the micronaire value, lower the value, finer is the fiber and vice-versa. The lowest micronaire value was recorded in the hybrid Shakti 9 BG II (3.5) and highest micronaire value (4.9) was recorded in hybrids KSCH 204 BG II and RCH 569 BG II.

Fiber strength: Maximum fiber strength (tenacity) was observed in the hybrid Bioseed 6539 BG II (27.2 g/tex) whereas, lowest was recorded in the hybrid RCH 653 BG II (21.3 g/tex).

Cotton leaf curl virus disease: Onlt two hybrids RCH 650 and Bio 6317 were free from cotton leaf curl virus disease.

Conclusion : On the basis of both the pickings i.e. first 155 DAS and second 184 DAS the hybrids KSCH 204 BG II, KSCH 211 BG II, RCH 653 BG II, Grand BG II, Border 507 BGII, Mist BG II and KSCH 210 BGII were found promising as they yielded significantly higher than the popular *Bt* hybrids RCH 134 BG II, Bioseed 6488 BG II and Ankur 3028 BG II. The hybrids DPC 3083 BG II and Platinum 605 BG II yielded significantly higher than the popular *Bt* Hybrids RCH 134 BG II and Bio 6488 BG II only. The hybrids KSCH 204 BG II and KSCH 211 BG II yielded significantly higher than all the non *Bt* checks. The hybrids KSCH 204 BG II, KSCH 211, BG II RCH 653 BG II, Grand BG II and Border 507 BGII yielded significantly higher than all the non *Bt* checks except H 1098-i. The hybrid Mist BG II yielded significantly higher than the non *Bt* checks H 1117, H 1226 and H 1236.

Sr. No.	Name	Yield (kg/ha)
1	KSCH 204 BGII	3340
2	KSCH 211 BGII	3205
3	RCH 653 BGII	3162
4	Grand BGII	3162
5	Border 507 BGII	3087
6	Mist BGII	2967
7	KSCH 210 BGII	2840
8	DPC 3083 BGII	2792
9	Platinum 605 BGII	2777
RCH 134 BG II		1524
Bioseed 6488 BG II		2029
Ankur 3028 BG II		2321
Non *Bt* Variety check H 1117		1510
Non *Bt* Variety check H 1226		2478
Non *Bt* Variety check H 1236		2307
Non *Bt* Variety check H 1098-i		2692
Non *Bt* Hybrid check HHH 223		2549
C.D. (kg/ha) / C.V. (%)		**481/13.02**

Recommendation: It can be concluded on the basis of this year data that amongst all the *Bt* hybrids tested, the hybrids *viz.* KSCH 204 BGII, KSCH 211 BGII, RCH 653 BGII, Grand BGII, Border 507 BGII, Mist BGII, KSCH 210 BGII, DPC 3083 BGII and Platinum 605 BGII were found promising as they yielded higher than the popular *Bt* hybrids and non *Bt* checks.

Conclusion on the basis of three years data:

Name	Yield (kg/ha)			
	2010	2011	2012	Average
Ankur 3028 BG II	3560	3009	2321	2963
JKCH 1050 BG II	3416	3138	2293	2949
MRC 7017 BG II	2922	3318	2563	2934
Mist BG II	2263	3472	2967	2901
Pancham 541 BG II	3436	3215	1952	2868
H1226 (non-*Bt* check)	3148	2855	2478	2827
VICH 310 BG II	3580	2803	2087	2823
Bio 6488 BG II	2963	2469	2029	2487
Bio 6588 BG II	2593	3035	1759	2462
Bio 2113 Bunty BG II	2119	3138	2108	2455
RCH 134 BG II	2963	2803	1524	2430
NCS 855 BG II Raghav	2428	2418	2108	2318
MRC 7361 BG II	2695	3524	187	2135
Ankur Jai BG II	1955	2186	1980	2040
RCH 569 BG II	2942	2135	897	1991
VICH 309 BG II	2160	2135	1610	1968
Bioseed 6317 BG II	1955	2135	1638	1909
NCEH 31 BG II Yuvraj	1523	1852	557	1311

Yield performance and reaction to biotic stresses of different hybrids/ varieties during 2013

S.No.	Variety/hybrid	Seed cotton yield (kg/ha)	CLCuD reaction	Whitefly/ leaf	Leaf hopper/ leaf	Thrips/ leaf	Boll damage by BW (%)	Locule damage by BW (%)
1	RCH 773	3549	MS	14.2	2.1	0.40	0	0
2	RCH 653	3025	S	16.5	0.5	0.40	0	0
3	Border	2994	S	19.3	0.4	0.27	2.96	0
4	NCS 459 (Suma)	2978	S	17.2	0.9	0.63	2.15	0
5	Surpass IT 905 *Bt*	2948	S	18.0	0.4	0.67	0	0
6	JK 0109	2917	S	15.9	0.6	0.07	0	0
7	JK 1947 X - Gene	2870	MS	20.1	0.5	0.67	0	0
8	SO 7 H 878 BGII	2824	MR	20.3	0.8	0.27	0	0
9	MRC 7361 BGII	2809	S	18.4	0.7	0.57	1.39	0.73
10	Bunty	2809	R	17.9	0.7	0.80	0	0
11	RCH 650	2747	MS	16.8	0.7	0.67	0.99	0.12
12	PRCH 7799 (Zordar)	2747	MS	16.5	0.5	0.53	0	0
13	RCH 776	2716	S	16.7	1.0	0.37	0	0
14	KSCH 211	2701	S	18.0	0.4	0.60	0	0
15	SP 7010 BG II	2701	S	19.7	0.5	0.47	0	0
16	KSCH 218	2562	S	13.8	0.5	0.40	0	0
17	MH 5302	2546	S	18.9	0.8	0.47	0	0
18	Bio 6488 BGII	2515	S	20.0	0.9	0.33	0	0
19	KCH 999 BG II	2469	HS	11.0	0.4	0.53	0	0
20	JK 1050 X - Gene	2469	S	19.0	0.6	0.47	0.9	0.12
21	Bio 6588 BG II	2438	S	16.2	1.2	0.40	0	0
22	RCH 791	2423	R	17.7	0.7	0.60	2.26	0
23	PCH 877 Leo cot BGII	2407	S	12.2	0.7	0.53	0	0
24	NCS 855 (Raghav)	2392	S	17.6	0.7	0.43	0	0
25	NCS 4455	2377	S	17.7	0.7	0.47	3.33	0
26	DPC 3083	2330	S	16.0	0.5	0.20	0	0
27	KSCH 213	2299	S	16.0	0.5	0.60	0	0
28	MRC 7041 BGII	2269	S	17.3	0.7	0.53	0	0
29	H 1226	2222	S	16.0	1.7	0.50	3.24	1.89
30	SP 7007	2222	S	12.8	0.7	0.53	0.79	0.21
31	HHH 223	2191	MS	13.9	1.6	0.43	1.1	0
32	MH 5304	2083	S	13.3	0.7	0.50	1.69	0
33	RCH 602	2068	MS	5.7	0.2	0.57	0	0
34	MRC 7017 BGII	2068	S	16.3	0.6	0.53	1.31	0.91
35	H 1300	2052	HS	15.2	1.3	0.40	0	0
36	H 1098-i	2037	S	17.2	2.0	0.73	2.33	1
37	Pancham 541	1975	HS	18.2	0.4	0.27	0	0
38	PRCH 333 Mahi BG II	1975	HS	15.9	0.7	0.47	0	0
39	Bio 6317	1944	S	17.7	0.5	0.63	0	0
40	SWCH 4713	1867	S	13.6	2.1	0.40	0	0
41	H 1236	1852	HS	16.6	2.0	0.43	2.06	0
42	VICH 310	1806	HS	19.3	0.5	0.47	1.09	0.13
43	JK 1050 BGII	1759	MS	17.9	0.4	0.47	0	0

Contd...

44	PCH 9609 Sirhind	1728	S	13.3	0.5	0.60	0	0
45	H 1117	1636	HS	16.7	1.9	0.63	1.64	0.82
46	RCH 134 BG II	1605	HS	18.0	2.1	0.40	1.29	0.16
47	KSCH 209	1590	HS	17.4	0.7	0.53	0	0
48	KSCH 210	1543	HS	19.4	0.7	0.40	0	0
49	NCS 9002 (Balwan)	1528	S	16.2	0.7	0.57	0	0
50	SWCH 4704 (US 21BGII)	1512	S	18.7	1.7	0.53	2.44	0
51	KSCH 215	1481	MS	15.6	0.6	0.47	1.45	0.18
52	RCH 134 BG I	1404	S	14.8	1.7	0.60	0.99	0.25
53	KCH 311 BG II	1327	HS	17.0	0.6	0.40	0	0
54	PRCH 711	1296	HS	11.1	1.0	0.23	0	0
55	Jadoo	1219	S	16.3	0.6	0.50	0	0
56	Western Nirogi 151	1219	S	19.8	0.6	0.57	1.45	0
57	KSCH 201	386	HS	15.9	0.6	0.53	1.56	0.79

0-10: Immune/ Disease free, 10.1-20: Resistant, 21-30: Moderately resistant, 31-40: Moderately susceptible, 41-50: Susceptible, Above 50: Highly susceptible, As per AICCIP CLCuD scale 0 -6 basis

On the basis of two years data i.e. 2012 and 2013 the following hybrids were found promising for cultivation in the Haryana state.

Name	Yield (kg/ha)		
	2012	2013	**Average**
RCH 653 BG II (Rasi Seeds)	3162	3025	**3093**
MRC 7017 BG II (Mahyco Seeds)	2563	2068	**2315**
RCH 650 BG II (Rasi Seeds)	2336	2747	**2541**
KSCH 201 BG II (Kohinoor Seeds)	2023	694	**1359**
SP 7007 BGII (Surpass)	1838	2948	**2393**
JKCH 1050 BG II (JK Seeds)	2293	1759	**2026**
Bio 2113 Bunty BG II	2108	2809	**2458**
KSCH 211 BG II (Kohinoor Seeds)	3205	2701	**2953**
Pancham 541 BG II (Krishidhan)	1952	1975	**1964**
H1226(non-*Bt* check)	2478	2222	**2350**
KSCH 218 BG II (Kohinoor Seeds)	2564	2562	**2563**
VICH 310 BG II (Vikram Seeds)	2087	1806	**1946**
Bioseed 6588 BG II	1759	2438	**2099**
NCS 855 BG II Raghav (Nuziveedu)	2108	2392	**2250**
RCH 134 BG II (Rasi Seeds)	1524	1605	**1564**
KSCH 209 BG II (Kohinoor Seeds)	2562	1590	**2076**
Bioseed 6488 BG II	2029	2515	**2272**
KSCH 210 BG II (Kohinoor Seeds)	2840	1543	**2192**
RCH 602 BG II (Rasi Seeds)	1268	2068	**1668**
NCS9002 BG II Balwan(Nuziveedu)	755	1528	**1141**
Bioseed 6317 BG II	1638	1944	**1791**
MRC 7361 BG II (Mahyco Seeds)	187	2809	**1498**
KSCH 213 BG II (Kohinoor Seeds)	2265	2299	**2282**

Recommendation : On the basis of three years data the *Bt* hybrids *viz.,* Ankur 3028 BG II, JKCH 1050 BG II, MRC 7017 (Nikki), Mist BG II, Pancham BG II, VICH 310 BG II, Bio 6488 BG II, Bio 6588 BG II, Bio 2113-2 (Bunty), RCH 134 BG II, NCS 855 (Raghav), MRC 7361 BG II and Ankur Jai BG II can be recommended for cultivation.

The hybrids RCH 773 BGII, RCH 653 BGII, Border, NCS 459 (Suma), Surpass IT 905, JK 0109 BGII, JK 1947 X – Gene, SO 7 H 878 BGII, MRC 7361 BGII, Bunty, RCH 650, PRCH 7799 (Zordar), RCH 776, KSCH 211 and SP 7010 BG II yielded more than27 q/ha and hence these hybrids can be recommended for cultivation.

On the basis of performance for seed cotton yield, maturity duration, insect pest and disease reaction and fibre quality data promising *Bt* cotton hybrids, non *Bt* varieties/hybrids were identified and recommendation is sent every year to Department of Agriculture, Government of Haryana so that it can encourage good performing hybrids/varieties and ban / discourage poor yielding hybrids to enhance the state cotton productivity along with other management practices.

List of poor yielding *Bt* cotton hybrids on the basis their performance of 2013-14

On the basis of four years data *i.e.* 2010, 2011, 2012 and 2013 the following hybrids were found promising for cultivation in the Haryana state.

Name	Yield (kg/ha)				
	2010	2011	2012	2013	**Average**
MRC 7017 BG II (Mahyco Seeds)	~~2922~~	~~3318~~	~~2563~~	~~2068~~	~~**2718**~~
H1226(non-*Bt* check)	3148	2855	2478	2222	**2676**
JKCH 1050 BG II (JK Seeds)	3416	3138	2293	1759	**2652**
Pancham 541 BG II (Krishidhan)	3436	3215	1952	1975	**2645**
VICH 310 BG II (Vikram Seeds)	3580	2803	2087	1806	**2569**
Bio 2113 Bunty BG II	2119	3138	2108	2809	**2543**
Bioseed 6488 BG II	2963	2469	2029	2515	**2494**
Bioseed 6588 BG II	2593	3035	1759	2438	**2456**
NCS 855 BG II Raghav (Nuziveedu)	2428	2418	2108	2392	**2336**
MRC 7361 BG II (Mahyco Seeds)	2695	3524	187	2809	**2304**
RCH 134 BG II (Rasi Seeds)	2963	2803	1524	1605	**2224**
Bioseed 6317 BG II	1955	2135	1638	1944	**1918**

Performance of *Bt* hybrids under irrigated and restricted irrigation (RI) conditions

Sr No.	Name of the *Bt* hybrid	2012Yield (kg/ha)		2013 Yield (kg/ha)		**Average yield(kg/ha)**	
		Irrigated	Restri. Irri.	Irrigated	Restri. Irri.	**Irrigated**	**Restri. Irri.**
1	DPC 3083	2792	3512	2330	1999	**2561**	**2756**
2	BUNTY	2108	3219	2809	2443	**2458.5**	**2831**
3	MRC 7017 (Nikki)	2563	3005	2068	2156	**2315.5**	**2581**
4	BIO 6588	1759	2222	2438	2770	**2098.5**	**2496**
5	SP 7007	1838	2606	2222	1228	**2030**	**1917**
6	PANCHAM 541	1952	2423	1975	1267	**1963.5**	**1845**
7	VICH 310	2087	2707	1806	879	**1946.5**	**1793**
8	RCH 134	1524	1856	2038	1254	**1781**	**1605**
9	MRC 7361	187	1418	2809	1790	**1498**	**1604**

Sr. No.	Name of hybrid/variety	Yield (kg/ha)	CLCuD reaction
1	KSCH 215	1481	S
2	RCH 134 BG I	1404	S
3	KCH 311 BG II (ATM)	1327	HS
4	PRCH 711 (Suraksha)	1296	HS
5	Jadoo KCH 14 K 59 BG	1219	S
6	Western Nirogi 151	1219	S
7	KSCH 201	386	HS

Recommendation: On the basis of four years data the *Bt* hybrids *viz.* MRC 7017 BG II, JKCH 1050 BG II, Pancham 541 BG II , VICH 310 BG II, Bio 2113 Bunty BG II, Bioseed 6488, Bioseed 6588 BG II, NCS 855 BG II Raghav can be recommended for cultivation.

Evaluation of *Bt* hyrids for restricted water availability : As water is becoming a limiting factor so it is also essential to identify the *Bt* cotton hybrids which perform better under restricted moisture condition. In this experiment irrigation was applied for sowing purpose only and after that crop was kept rain fed through the crop season.This experiment was done for the 2012 and 2013. The *Bt* cotton hybrid wewe selected which performed good under water stress conditions. Same hybrids also evalution under irrigated condition.

On the basis of mean performance both the years it can be conluded thath*Bt* cotton hybrids namely DPC 3083, Bunty,MRC 7017 and Bio 6588 performed better under restricted irrigation conditions as compared to irrigated condition. Hence their cultivation was advocated for areas with less water availability.

The seed development in some of the hybrids / varieties was very poor due to abnormal weather conditions and high incidence of sucking pests which resulted in excessively high ginning out turn and such inflated values may be considered as an exception case due to environmental factors.

Reaction of cotton leaf curl virus disease : The intensity of cotton leaf curl disease (CLCuD) reaction was recorded on 0 to 6 grades and per cent disease index was calculated as per standard AICCIP formula. The observation with regard to Cotton Leaf curl virus disease is given in below:

Highly resistant: 1 Bunty (Bio 2113-2)
Resistant hybrids: 2 (RCH 602 and RCH 650)

Moderately resistant hybrids: 5(H 1098-I, RCH 791, Super 6588, Bio 6588, RCH 653 and Ankur3224)

Boll weight: Maximum boll weight was recorded in SO 7 H878 BGII (4.00 g) followed by RCH 773 BG II (3.90 g). The lowest boll weight among the non *Bt* variety was recorded H 1226 and KDCHHN 9632 BG II (2.70 g)

Ginning Outturn: The ginning out turn ranged from 32.7 per cent (RCH 791 andPCH 9602) to 41.8 per cent (Bio 6165). In general ginning out turn during this year was on higher side due to poor development of seed.

Fiber quality: The fiber samples were sent to CIRCOT (ICAR) laboratory for the testing of 2.5 per cent Span length, Uniformity ratio, Micronaire value and Fiber strength2.5 per cent Span length:

The maximum 2.5 per cent span length

Performance of varieties/hybrids evaluated during 2014 for different traits

Sr.No	Name	Mean Data Sucking pests population/leaf			Reaction to CLCuD	Seed cotton yield (kg/ha)	Per cent yield in first picking
		Whitefly	Leafhopper	Thrips			
1	RCH 602	8.00	0.00	2.17	R	**2957**	87.3
2	ATM (KCH 311)	12.33	0.25	0.00	S	2530	87.8
3	Bunty (Bio 2113-2)	10.50	0.25	0.42	HR	2513	94.6
4	RCH 791	11.75	0.83	0.92	MR	2410	93.6
5	PCH 9604	11.25	0.83	1.00	MS	2325	89.0
6	SO 7 H878 BGII	14.67	0.42	0.00	MS	2308	94.1
7	Super 6488 (6539-2)	13.33	0.50	0.00	MS	2308	90.4
8	Bio 6165	12.17	0.00	0.00	MS	2291	85.1
9	JK TARZAN	12.33	0.75	1.67	MS	2291	88.1
10	Ankur 3028	13.83	0.25	0.00	MS	2274	84.2
11	PCH 9609	10.25	0.33	0.83	MS	2239	85.5
12	Super 6588 (2510-2)	11.00	0.00	0.83	MR	2205	92.2
13	SP 7007	11.17	0.67	1.50	S	2188	90.6
14	NCS 9002 (Balwan)	14.33	0.17	2.42	MS	2188	88.3
15	Bio 6588	11.75	0.25	0.50	MR	2171	92.1
16	RCH 653	10.67	0.75	1.92	MR	2171	95.3
17	RCH 773	24.08	0.67	0.67	MS	2154	95.2
18	KCH 999	13.50	0.83	0.00	S	2154	67.5
19	NCS 855 (Raghav)	13.92	0.33	1.00	MS	2120	93.5
20	NCS 9013	12.00	0.33	2.17	MS	2120	92.7
21	RCH 650	10.92	0.17	1.17	R	2060	94.6
22	RCH 776	11.00	0.17	0.00	MS	2026	95.4
23	RCH 314	11.50	0.42	1.58	MS	2017	93.2
24	Bio 6488	13.08	0.50	0.00	MS	2000	85.5
25	JKCH 8940	13.67	0.00	0.00	MS	1966	94.8
26	H 1098-i	14.00	0.25	0.33	MR	1863	90.8
27	DPC 3085 BGII	11.92	0.42	1.08	MS	1863	95.4
28	Sikander	13.83	0.50	0.00	MS	1846	90.7
29	DPC 3083 BGII	16.33	0.58	1.25	S	1821	93.9
30	H 1226	11.42	0.17	0.67	MS	1778	88.5
31	PCH 877	18.67	0.17	1.50	MS	1761	91.3
32	HHH 223	10.67	0.42	0.67	MS	1726	94.1
33	Bio 6317-2	12.25	0.00	0.00	MS	1726	90.1
34	JKCH 1050	19.75	0.00	1.67	S	1726	**96.0**
35	SP 7010	10.75	0.75	0.50	S	1692	94.9
36	JKCH 0109 BGII	13.00	0.83	0.33	MS	1675	93.9
37	PCH 1414 (Leo cot)	19.17	0.42	1.83	S	1675	93.9
38	PCH 9602	20.17	0.67	2.58	S	1667	94.4
39	Ankur 3224	14.75	0.33	2.17	MR	1650	92.2
40	KDCHH 516	13.08	0.42	1.25	MS	1624	92.6
41	Ankur 3244	10.75	0.83	0.00	MS	1607	80.9
42	KDCHHN 9632	9.50	0.00	1.08	MS	1590	94.6
43	SP 7171	10.67	0.75	1.67	MS	1496	93.7
44	Bullet (KCH 707)	15.83	1.00	1.58	S	1470	80.2
45	JKCH 1947	13.83	0.25	2.50	MS	1436	92.9
46	H 1300	15.58	0.17	0.50	S	1350	92.4
47	H 1117	12.58	0.50	0.17	S	1333	84.6
48	KDCHH 541	18.33	0.33	2.25	S	1265	91.9
49	Jadoo (KCH 14K59)	15.58	0.50	1.33	S	1214	88.7
50	H 1236	16.58	0.83	0.00	S	1111	89.2
51	Jackpot	11.92	0.17	1.42	MS	923	83.3
	Range	8.0(RCH 602) - 24.08(RCH 773)	0.0-1.0	0.0-2.58	HR - S	2957(RCH 602) - 923(Jackpot)	67.5 (KCH 999)- 96.0 (JKCH 1050)

was recorded in the hybrid Ankur 3244 (31.0 mm) followed by KCH 999 (30.3 mm), ATM and Bullet (29.5 mm). The minimum was observed in the non-*Bt* check variety H1117 (22.9 mm).

Uniformity ratio : Uniformity ratio determines the fiber quality by describing the uniformity in the fiber length. It was maximum in the *Bt* hybrids Bunty (52 %) followed by H 1117 (51%) and H 1226, KDCHH541, RCH 650, DPC 3085, RCH 773(50%). Whereas, it was lowest in the *Bt* hybrid PCH 9602 (44%).

Micronaire value: Fineness of the fiber is measured by the micronaire value, lowers the value, finer is the fiber and vice-versa. The lowest micronaire value was recorded in the hybrid KDCHH 516 and H1226 (3.8) and highest micronaire value (5.1) was recorded in hybrids Bio 6317-2 and DPC3083.

Fiber strength: Maximum fiber strength (tenacity) was observed in the *Bt* cotton hybrid Bullet (24.9 g/tex) whereas, lowest was recorded in the variety H 1117 (18.5 g/tex).

S. No.	Entry code	Per cent bollworm infestation	Aphid/flower bud
1	H1117 (non *Bt* check variety)	0.80	18
2	H1226 (non *Bt* check variety)	1.55	15
3	H 1236 (non *Bt* check variety)	0.60	20
4	H1098-i (non *Bt* check variety)	1.39	12
5	Bio 6488 BGII	0.00	10
6	Bio 6588 BG II	0.00	15
7	Jadoo KCH 14 K 59 BG	0.00	10
8	JK 1050 BG II	0.00	13

On the basis of seed cotton yield of both the pickings, the highest yield was recorded in *Bt* cotton hybrid RCH 602 BG II (2957 kg/ha) followed by ATM 311 (2530 kg/ha) and Bunty (2513 kg/ha). Other promising *Bt* cotton hybrids were RCH 791 BG II (2410 kg/ha), PCH 9604 (2325 kg/ha),SO7 H 878 BG II (2308 kg/ha), Super 6488 (2308 kg/ha), Bio 6165 (2291 kg/ha), JK Tarzan (2291 kg/ha), Ankur 3028 (2274 kg/ha), PCH 9609 (2239 kg/ha), Super 6588 (2205 kg/ha). These hybrids have good seed cotton yield and moderately susceptible or moderately resistant reaction to cotton leaf curl virus disease.

Only one *Bt* cotton hybrid RCH 602 BG II (2957 kg/ha) significantly out yielded the most popular check hybrid Bio 6588 BG II (2171 kg/ha). The lowest yield was recorded in the *Bt* hybrid Jackpot (923 kg/ha).

Cotton wheat relay cropping : This experiment was started in the year 2013 and it was repeated in 2014. During the year 2013 a total of four pickings were done. First picking was done on 18.1.2013, second on 15.11.2013 as conventional practice and after wheat crop was sown in these plots and third picking on 17.12.2013 and forth picking was done on 18.01.2014. Under relay cropping system a yield from 15 kg/ha to 336 kg/ha were harvested in third picking and in fourth picking there was no yield from any of the plot from different BT hybrids and non *Bt* varieties/hybrids ranged

Pest status:

A: Observation at the time of sowing wheat crop: 18:11:2013

1. Bollworm infestation was not found in any of the entry.
2. Sucking pests (thrips, leafhopper, aphid and whitefly) infestation was also not observed.

B: observation on 9:1:2014

1. In non *Bt* cotton hybrids bollworms infestation was observed from 0.60 to 1.55 per cent but bollworm infestation was nil in *Bt* hybrids.
2. Aphid infestation was observed in cotton flower buds (10-15 aphids) but not on wheat crop.

During 2014 under relay system seed cotton yield was less than 50 kg/ha in third picking and no need to go for fourth picking. From this experiment it was concluded that under Haryana condition relay cropping of wheat is not recommended if normal maturity duration hybrids/varieties are planted because they produce better seed cotton yield under conventional practice i.e. about 180 days after sowing than late maturing hybrids (normal + relay yield). This practice may be recommended for specific conditions like due to some environmental conditions crop maturity period may be prolonged further and secondly a farmer had grown late maturity duration hybrid by unknowingly.

2

Impact of elevated CO_2 on cotton productivity – A climate resilience viewpoint

N., GOPALAKRISHNAN, S.E.S.A., KHADER, A.H.PRAKASH AND K. SANKARANARAYANAN

Central Institute for Cotton Research, Regional Station, Coimbatore-641003

E-mail : gopalcotton@gmail.com

Cotton is an important commercial crop for the economy of India, with recent global position of leading in production ahead of China, and offering livelihood security for the Indian farming community. It is the crop of commerce, history, civilization, symbol of economic prosperity to millions of farmers, being grown in the country on variable land holdings, different planting dates, soil and water holding conditions and largely under rainfed situations. Sustainability of production, overcoming biotic and abiotic stresses, meeting requisite quality standards and maintaining economic cost of cultivation are some of the challenges that need continued attention of the scientists, development officials, field functionaries and cotton growers. Climate change has also become a major national issue as well as global concern. More than 65 per cent of Indian populations rely on agriculture for their livelihood, which is directly dependant on climate. With such an importance in national economy for providing livelihood security to 60 million people including all the stake holders of cotton value chain, the climate change and its likely impact on cotton crop is fast gaining importance.

Changes in the major independent variables *viz.,* CO_2, temperature and water to the extent that they actually occur may alter plant growth rates, biomass reservoirs and plant community composition at local, regional and global scales. The global atmospheric concentration of carbon dioxide (CO_2) has increased from a pre industrial level of about 280 to 379 ppm. in 2005, and a value of 770 ppm. (double the current levels) is expected for 2100 (IPCC, 2007). Such an increase in CO_2 levels affects the biology of living organisms, including insects (Yin *et al.,* 2010).

Reports of Inter-Governmental Panel on Climate Change (IPCC) revealed that the earth temperature has already increased by 0.74°C between 1906 and 2005 due to increase in anthropogenic emissions of greenhouse gases. For Indian region under south Asia, the IPCC has projected 0.5-1.2°C rise in temperature by 2020, 0.88-3.16 °C by 2050 and 1.56-5.44°C by 2080 depending on the pace in future development scenario. Study showed that global temperature increase might exceed to the extent of 1.8-4.0°C by the turn of 21st century resulting in anticipated greater instability in agricultural (food, feed and fibre) production (Aggarwal, 2008). The increase in mean air temperature is influencing reduction of snow cover and discharge of river water. The expected rise in temperature in higher latitudes will be much more than at equatorial regions. Amongst the seasons, the temperature increases are likely to be much higher in winter (*rabi*) season than in rainy (*kharif*) season.

Agriculture contributes about 28 per cent of green house gas emissions, primarily due to methane emission, especially in rice cultivation, enteric fermentation in ruminant animals, and nitrous oxides from application of manures and fertilizers to the soils. Increasing atmospheric concentration of CO_2 at alarming rates (1.9 ppm/year) in recent years than the natural growth rate causes a concern. Although global atmospheric concentration of methane (CH_4) was at 1774 parts per billion (ppb) in 2005 and remained nearly constant thereafter, yet, increase in nitrous oxide concentration to 319 ppb in 2005 from pre-industrial value of about 270 ppb again is a concern (Sankaranarayanan *et al.,* 2010)

Increased concentrations of CO_2 may influence the development of insect herbivores directly or indirectly through the effects of a CO_2-enriched environment on host plant chemistry. Elevated CO_2 generally increases photosynthesis rates, above ground biomass, yield, and carbon:nitrogen (C:N) ratios and reduces N concentrations, thus impacting the production of plant nutrients . In turn, lower foliar N and protein concentrations, which cause reductions in leaf nutritional quality (Mattson, 1980; Johns and Hugher, 2002), increase consumption rates, mortality, and development times, and thus decrease the fitness of insect herbivores. Cascade effects of elevated CO_2through plants are often considered to be responsible for the main impacts on the performance of herbivorous insects.

Many dry regions may experience a decrease in precipitation, while some others will become wetter. Precipitation is likely to increase in all time slices in all months except during December-February when it is likely to decrease. Reports indicated its decreasing trend in south western and central parts of India, while increasing trend in Punjab, western Rajasthan, Gangetic west Bengal and sub Himalayan west Bengal (Ramakrishna *et al.,* 2006). As a result of these shifts, crop performances can be considerably influenced. Extensive warming (by 4°C) in Indian sub continent could cause significant reduction in crop yields (25-40 %) in the absence of adaptation and carbon fertilization (Rosenziveig and Parry 1994) although appropriate adaptations would reduce the magnitude of losses. Since warming was more or less the same throughout India, still some areas in western coastal districts would lose heavily, whereas other districts in eastern states would even benefit slightly (FAO 2000).

Elevated CO_2 : Of the four major green house gases causing a concern regarding the global climate change, CO_2 is by far the most significant one in respect of cotton production. CO_2 in the atmosphere is observed to have increased by about 80 ppm/m^2 of air, since the beginning of the industrial revolution towards the end of the 18th century. The current value is about 398 ppm and the rate of increase is estimated to be 1.8 ppm/year . This increase in CO_2 has profound implications on global warming and shifts in precipitation at regional and continental scale. In general, increase in atmospheric CO_2 increases the quantum of yield produced photosynthetically, net photosynthesis, biomass production and ultimate output in term of grain, seed, oil and fibre. Besides greater output, higher inputs (light, nutrient and water) use efficiency in cultivated crops are expected to be realized; and the same at a much greater pace in C3 plants (cotton, rice, wheat) over C4 plants (maize, sugarcane).

In a typical cotton field, the plants will extract about 11.34 tonnes of CO_2/ha to make the fibre (lint), oil (seed), protein (feed) and other plant parts. Out of it, nearly one tenth that is taken from the air is used to produce cotton fibres and about 0.5 tones is extracted to produce some 0.19 tonnes of vegetable oil. In the process, around 7.9 tonnes of O2 is released back into the atmosphere. Thus, more than 450 m. tons of CO_2 were removed by cotton plants during whole growing season while more than 36.3 M tones of CO_2 that removed from the air were used to form the cellulose in the fibre and was bound in fibres for a considerable period of time and most of the CO_2 was deposited back as an amendment to the soil through carbon sequestration (return of carbon). Carbon sequestered in the world cotton fibre supply is equivalent of taking 7.25 million passenger vehicles from the highways (Sankaranarayanan *et al.,* 2010). Effect of elevated CO_2 on cotton growth and development is more apparent through significantly greater leaf area and higher net photosynthetic rates associated with lower dark respiration and light compensation point than plants grown in ambient CO_2 (Zhao *et al.,* 2004). Greater assimilation rate of plants grown in elevated CO_2 enables in incorporating 30 per cent more biomass during the first 36 days of growth Higher assimilation is due to higher chlorophyll-a concentration following CO_2 enrichment (550 ppm) than ambient condition even under different moisture regimes. Study showed average chlorophyll content was higher both in the wet (7.1 %) treatment and dry (8.2 %) treatments (Printer *et al.,* 1994b). The results clearly indicated that elevated CO_2 or its enrichment produced higher chlorophyll content and consequently, higher output in cotton plants.

Cotton plants grown under elevated CO_2 atmosphere fixed 16% more CO_2 than the ambient grown plants (Khader et al. 2004). At the onset of water stress, the photosynthetic activity declined from the initial level of 24μ mol CO_2 to a level of 5 μ mol $CO_2/m^2/s$ within six days (Table1). Even diurnal changes in photosynthesis rate were also observed under free-air carbon dioxide enrichment (FACE). Midday net photosynthesis rates of both leaves and canopies were 19-41 % higher in the CO2-enriched plots than in control plots since midday stomatal conductance values of leaves were 13-44 % greater in control plants than in CO_2-enriched plants (Hileman et al. 1994). There was no effect of CO_2 enrichment on transpiration of crop, grown under well-watered and high-fertility conditions (Dugas et al. 1994) although the CO_2 fluxes were significantly higher in the free-air carbon dioxide enrichment (550 ppm) than at ambient level and also higher with wet than dry irrigation level (Nakayama et al. 1994).

Biochemical constituents in plants viz., leaf carbohydrate content were also increased by FACE and the increments were much more pronounced in the stems and roots. Starch and soluble sugars in leaves in FACE tend to be consistently greater than in control leaves. Thus, the significant effect of CO_2 enrichment on starch-accumulating plants is through increase of nonstructural carbohydrate, especially starch, in non leaf storage pools (Hendrix *et al.,* 1994). Although N and protein

Table 1. Effect of elevated CO_2 and water stress on photosynthetic rate ($mmol/m^2/s$) in cotton

Treatment		Days after imposition of stress (d)						**Mean**
		1	2	3	4	5	6	
Elevated CO_2 (650ppm)	Unstressed	25.1	25.4	24.9	25.6	25.5	24.8	**25.2**
Ambient(330ppm)	Stressed	23.7	24.6	21.5	14.3	7.7	5.2	**16.1**
	Unstressed	21.0	21.4	20.8	21.5	21.8	22.0	**21.4**
	Stressed	20.5	21.6	18.5	16.7	9.8	6.5	**15.5**

Adopted from Khader *et al.*, (2004)

concentrations in leaves, stems and roots were significantly lower in CO_2 enriched plants than in control, yet C: N ratios were higher for the free air CO_2 enrichment plants than the control (Huluka *et al.,* 1994) and there were no significant effects of interaction involving irrigation and CO_2. Reduction in tissue N and protein concentration and increase in C:N ratio following CO_2enrichment has important impact in agriculture and natural systems.

Physiologically, leaf water relations in a cotton plant under CO_2 enriched environment was also improved (Bhattacharya *et al.,* 1994). The atmosphere enriched with 550 ppm during the day light hours under full irrigation produced decreased stomatal conductance leading in increased leaf water potential. Under water stress conditions, FACE decreased the conductance throughout the season although the effect on leaf water potential is not consistent. Thus, FACE increased the season long biomass accumulation by 39 per cent under full irrigation and 34 per cent under deficit irrigation. The FACE treatment improved the water use efficiency to the same amount in well irrigated and water stress plots. These were confirmed in many studies also (Radin, 1992).

Free air CO_2 enrichment was also found to increase root dry weight and densities in cotton (Prior *et al.,* 1994). Vertical root pulling resistance, larger diameter taproots, dry weight and volume were also higher under CO_2 enrichment. The development of more robust taproot systems under CO_2 enriched environments may allow for greater carbohydrate storage to ensure root growth for continued exploration of the soil profile to meet nutrient and water needs during peak demand periods (Prior *et al.,* 1995). Evapotranspiration (ET), a better crop water use parameter for water relation studies, was, however, not significantly influenced by CO_2enrichment. This implies that irrigation water use would not have to be increased to produce cotton in a future high CO_2 world. However, if a concomitant change in climate occurs, such as global warming, ET in cotton may change in response to the changed weather condition (Hunsaker *et al.,* 1994).

Cotton plants, grown in elevated CO_2, had significantly higher seed cotton yield over that in ambient CO_2 as increase in harvestable yield by 43 per cent was observed at 550 ppm of CO_2 throughout the growing seasons (Nagy and Hendrey 1994). Similar results were also reported (yield increase to the tune of 40 and 43 per cent by Mauney *et al.,* (1994). and Khader *et al.,* (2004). Here, the increase in biomass and yield is attributed to increase in leaf area, more profuse flowering and longer period of root retention. Boll growth and developmental parameters under elevated atmospheric CO_2 did not affect any of the fibre parameters (Raja Reddy *et al.,* 1999).

Available data from greenhouse and laboratory studies suggests that leaf photosynthesis, crop growth and water-use efficiency of tropical plants might increase at higher CO_2 concentrations. However, under field conditions, abiotic (light, water or nutrients) or biotic (competition or herbivory) factors might limit these responses. In general, elevated atmospheric CO_2 concentrations seems to increase plant tolerance to stress, that include low water availability, high or low temperature and photo inhibition.

Temperature : Tropical plants may be more narrowly adapted to prevailing temperature regimes than are temperate plants, hence expected changes in temperature might be relatively more important in the tropics. Reduced transpiration due to decreased stomatal conductance could modify the effects of water stress as a cue for vegetative or reproductive phenology of plants in seasonal tropical areas (Hogan *et al.*, 1991).

Cotton requires warm days and relatively cool nights for optimum growth and development. Temperature significantly affects phenology, leaf expansion, internodes elongation, biomass production and the partitioning of assimilates to different plant parts. In the crop growth front, the seedlings were insensitive to rise in temperature from 20/12 to 40/ 32°C during the first 2 weeks of emergence, and after that, they were temperature sensitive (Reddy *et al.*,1995) since 40 and 50 per cent less biomass at 20/ 10°C and 40/30°C, respectively were observed as compared to optimum temperature of 30/ 20°C (Reddy *et al.,* 1992). Biomass of 13, 15 and 43 per cent were partitioned to ‘squares and bolls’ at 20/10°C, 25/15°C and 30/20 °C, respectively which reflects to some extent slower development at the temperatures lower than 30/ 20°C. Most of the squares and bolls were aborted above 30/20°C. When the temperature increased from 20/10 to 30/20o C, total plant weight increased by 36 per cent. Yet, boll weight was greatest at 30/20 o C, and least at both higher and lower temperatures. Boll growth was more temperature sensitive than vegetative growth . It was concluded from temperature studies that optimum temperature for maximum growth rate of leaves, main stem and fruiting branches was 30/22°C (Reddy *et al.*, 1995). This was also the optimum temperature for the quantum of squares and bolls retained/plant since the number of fruiting branches did not increase above 30/22°C.

Moreover, the plants grown at high temperature regimes lost their reproductive capacity to a greater extent than their ability to produce biomass. High temperature environments were also associated with cotton sterility and boll retention problems. Cotton plants grown from seedlings at 40°C for 12 hrs/ day shed all their squares. Plants grown from seedlings in the natural environment and exposed to daytime temperatures of 30, 35 or 40°C during the fruiting period accumulated 47, 5.7, and <1 per cent, respectively of their mass as bolls. Three week exposure to 40°C for 2 or 12 hrs/day resulted in 64 or 0 per cent bolls, respectively retained on the plants (Raja Reddy *et al.,*1992). Developmental rates, as depicted by the number of main stem nodes produced, were sensitive to temperature at 40/32°C although the number of fruiting branches did not increase above 30/22°C. All flower buds abscise from the plant grown at 40/32°C (Raja Reddy *et al.*,1995). Soil warming affects the rooting system as the soil temperature also increases.

Studies on the effect of temperature in different genotypes (Reddy *et al.*, 1992) revealed that pima cotton (Extra Long Staple) was found to be more sensitive to higher temperatures than the delta type of cotton plants. They reflected this high temperature sensitivity by producing no fruiting branches at 40/32°C, fewer branches at 35/27°C and more branches at 30/22°C, whereas the G. hirsutum plants produced the same number of fruiting branches in all these temperatures. Pima cotton exhibited greater damage to their reproductive structures at higher temperatures than the hirsutum cotton type. The study suggests that high temperature through climate change may affect the ELS cotton programme.

Higher temperatures (ambient plus 2°C) is also shown to reduce the lint yield with an overall average of 7 per cent (Pettigrew 2007). Changes in temperature, however, had a dramatic effect on boll set and fibre properties (Reddy *et al.,* 1999). Fibres were longer when bolls grew at less than optimal temperatures (25°C) for boll growth. As temperature increased, fibre length distributions were more uniform while fibre fineness and maturity increased linearly with the increase in temperature up to 26°C, but decreased at 32°C. Short-fibre content declined linearly from 17 to 26°C, but was higher at higher temperature. To the contrary, most fibre quality traits were little affected by varying the temperature regimes (Pettigrew 2007).

If the predicted global warming occurs, temperature extremes are likely to be much higher which will have a deleterious effects on the existing cultivars adapted to a moderate temperature. Hence, development of heat tolerant cotton cultivars with matching yields and desired fibre quality shall be a priority area of research.

CO_2 x Temperature : Predicting plant responses to changing atmospheric CO_2 and to the possible global warming by high temperature and their interaction are more important than the sole effect. Although rates of main stem node formation and the time required in producing the first square and first flower were not little influenced by atmospheric CO_2, yet these were very sensitive to temperature. Similarly, carbon dioxide levels did not alter the time required producing nodes; yet, number of branches produced was sensitive to both temperature and CO_2. The larger the number of bolls set on the lower branches of plants grown at high CO2, the larger is the sink for photosynthesis than plants grown at low CO_2. This may explain the reason for the observed reduction in number of fruit at the upper nodes of high CO_2 grown plants. More bolls and squares were produced and retained on plants grown in high CO_2 environments, except that none were produced in either CO_2 environment at 40/32°C (Reddy *et al.,* 1995).

Although higher CO_2increased final leaf size and rate of leaf expansion, yet, the effect was more pronounced at higher temperatures (Reddy *et al.,* 1994). The increase in whole plant leaf area with doubling of $CO_2$was due to small increases in individual leaf sizes and a large increase in the number of leaves on fruiting and vegetative branches. At 720 ppm of CO_2 enriched atmosphere, the plants had about 40 per cent more squares and bolls across temperatures than the 360 ppm (Reddy *et al.,* 1999). Cotton plants showed large responses to humidity and a very high level of CO_2 (700 ppm). In cotton plants, the enhanced dry matter yield due to doubled CO_2 concentration was 1.6 fold greater at low humidity than at high humidity (Wong 1993).

Khader (2014) observed that boll number in cotton plants grown throughout crop growth at elevated CO_2 level (650±50 ppm) increased significantly with 1 f C rise in temperature above ambient(30 bolls/plant) and decreased to 17 bolls/plant with further increase in temperature of 3 ^{f} C above ambient temperature

Nutrient management : FACE (550 ppm) often decreased tissue nutrient concentration, but increased total nutrient accumulation. Under elevated CO_2, field grown cotton was more nutrient efficient in terms of nutrient retrieval from the soil and nutrient utilization in the plant (Prior *et al.,* 1998). This enables more efficient fertilizer utilization, better economic returns for fertilizer expenditures and reduced environmental impact from agricultural fertilization practices in the future. A significant CO_2 interaction with N was observed for total bolls produced ($p < 0.001$) and retained ($p < 0.05$) (Reddy *et al.,* 2004). The bolls produced and retained/plant were significantly higher for the plants grown at elevated CO_2 and N+ conditions other than the treatments. Plants grown at ambient CO_2 and N+ condition and elevated CO_2 and N condition performed similarly for total bolls produced and retained. Thus, the study suggests the greater possibility in realization of higher nutrient efficiency under elevated CO_2.

Huluka *et al.,* (1994) found less nutrient concentration with elevated CO_2 levels but at sufficient range for all the tested elements except N, which was below the sufficiency. Reddy *et al.,* (2004) observed a similar result of leaf N concentration decreased with increasing CO_2 under low and high level of N. These low leaf N concentrations did not reduce the effect of elevated CO_2 producing higher lint yields and the response being highest for plants grown at elevated CO_2 and high N conditions. It is inferred that future elevated CO_2 will not have any deleterious effects on fibre quality and yield, if N supply is optimum.

Elevated CO_2 concentration and photosynthesis : Photosynthesis in C3 Plants is a consequence of a multi step and complicated process that involves several biological pathways. The Pathways are photosynthetic electron transport system (PETs), in which the light energy is altered into ATP and NADPH; The Calvin Benson cycle that is also known as a photosynthetic carbon fixation cycle in which CO_2 is fixed into carbohydrates, as well as assimilation, transport, and utilization of photoassimilates as the organic products of photosynthesis [Pego *et al.*, 2000; Eberhard *et al.*, 2008; Foyer *et al.*, 2012]. The two important steps, PETs and the Calvin Benson cycle, are under the control of many genes/gene products encoded from chloroplast as well as nuclear genomes. While the products of genes involved in photosynthesis have obvious functions, they operate together within the framework of an extensively coordinated photosynthetic network of genes, regulatory components, signaling factors, and metabolic processes (Nouri *et al.*, 2015). The expression of genes in both cellular organelles is highly variable and affected by a diverse range of environmental factors [Berry *et al.,* 2013]. Many environmental stresses such as drought, salinity, flooding, light, unfavorable temperatures, and its rapid fluctuations adversely affect the process of photosynthetic carbon metabolism in plants. It may alter the ultrastructure of the organelles, change the concentration of various pigments and metabolites as well as stomatal regulation [Pinheiro and Chaves, 2011; Berry *et al.*, 2013]. Several reports indicate that photosynthesis cascades are highly correlated with the accumulation of some important proteins such as ribulose-1,5 bisphosphate carboxylase/ oxygenase (RuBisCO) and other photosynthesis-related proteins [Maayan *et al.,* 2008]. To get insight into the photosynthetic gene expression and regulation under abiotic stresses, OMICS technologies such as genomics, transcriptomics, proteomics, and metabolomics can provide detailed information which can be later applied to improve plant yield potentials. In response to various abiotic stresses, plants continuously need to adjust their transcriptome profile [Gupta *et al.*, 2013].

Transcriptomic and proteomic approaches have emerged as powerful tools to analyze genome expression at the transcription and translational levels, respectively [Woodson and Chory, 2008]. These high-throughput technologies have been extensively accepted to study the expression of certain genes and proteins in response to different abiotic stresses [Blankenburg *et al.*, 2009]. Proteomics, as one of the cutting edge molecular techniques, efficiently deals with the functional molecular studies. Recently, improvement of techniques for isolation and purification of cell organelles and compartments gave new insights into organelle proteomics [Nouri and Komatsu, 2013]. Photosynthesis in plants is under the control of a complex network of proteins. Four major multisubunit protein complexes, photosystem (PS) I, PSII, the ATP synthase complex and cytochrome b6/f complex are involved in the process [Hippler *et al.*, 2001]. These proteins are greatly affected under abiotic stress conditions.

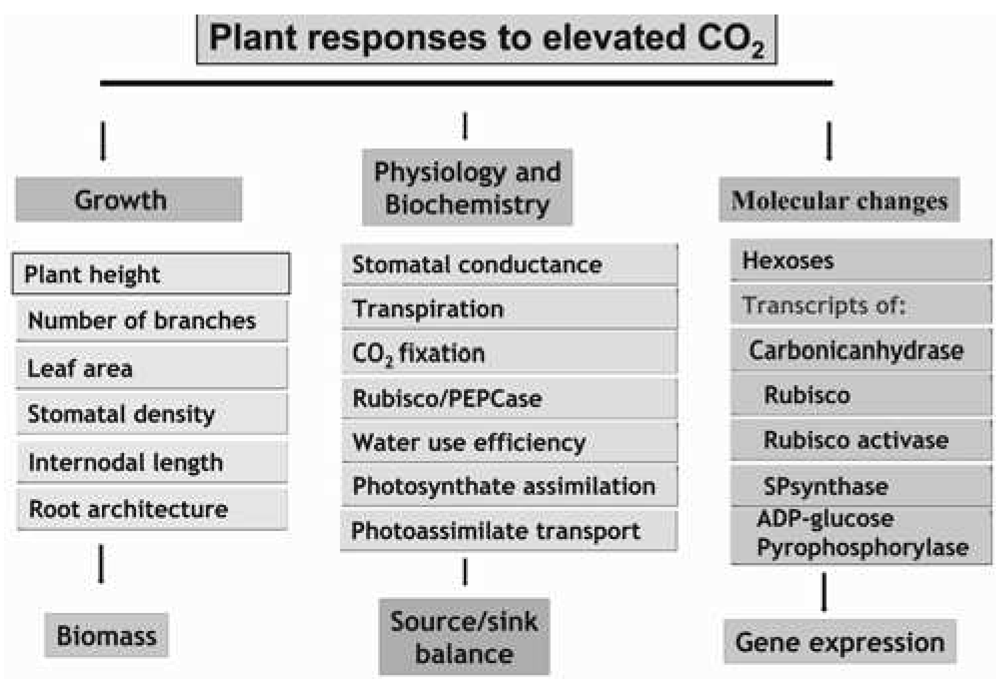
Plants with the metabolic pathways of C3 for carbon fixation are distributed worldwide. They represent over 95 per cent of the earth's plant species, especially in cold and wet climates, usually with low light intensity. In C3 plants, the photosynthetic Carbon Reduction or Calvin Benson cycle for CO_2 fixation produces a three carbon compound, phosphoglycerate. Therefore, plants utilizing this pathway are often named as C3 species [Taiz and Zeiger, 2010]. According to a systems biology analysis, the photosynthetic metabolism of C3 plants has a highly cooperative regulation in changing environments [Ahuja *et al.,* 2010]. Effects of environmental changes and abiotic stresses on photosynthesis system of many C3 plants, from stomatal conductance to carbon assimilation and from gene regulation to protein expression are well documented [Chaves *et al.,* 2009]. Various components are involved in the mechanism of photosynthesis in response to environmental stresses, including photosynthetic pigments and photosystems, the electron transport system, and CO_2 reduction pathways. Changes in CO_2 level of atmosphere is an environmental factor with the most direct and instant effect on photosynthesis. Global atmospheric CO_2 concentration of the earth is 380 ìL/L which is 40 per cent more than pre industrial times. Values are predicted to reach between 530 and 970 ìL/L by the end of this century [Prins *et al.,* 2011]. In theory, elevated CO_2 will directly affect the balance between photosynthetic carbon fixation and photorespiration. However, plant response to high $CO_2$is under the influence of several factors, including plant carbon fixation pathways. Foyer *et al.* (2012) reviewed the literature related to the C3 and C4 plant responses to elevated CO_2 concentration compared with those grown with ambient CO_2. Exposing C3 leaves to high CO_2, immediately increases net photosynthesis because of decreased photorespiration [Kramer, 1981; Bowes, 1991] and enhances the expression of genes associated with cyclic electron flow pathways. However, long-term elevated CO_2 often decreases photosynthetic capacity, RuBisCO activity and CO_2 fixation.

Crop residue : Assessing the impact of elevated atmospheric CO_2concentration on the global environment is improved by understanding the global Carbon (re)cycling. Carbon fixed within plant biomass ultimately enters the soil *via* plant residues. No significant difference was observed with respect to soil respiration or P mineralization immobilization between CO_2enrichment against ambient CO_2 conditions by application of crop residues. However, significantly greater net N immobilization was observed during the incubation in all soil types with elevated CO_2 treatment by application of crop residue. These results indicate that decomposition of plant residue may not be reduced by CO_2 enrichment, but N dynamics may be markedly changed (Torbert *et al.,* 1995). High CO_2environments without water stress, increased C storage in soil is likely, but it is less likely where water stress is a factor (Wood *et al.,* 1994).

Climate models : Crop simulation

modeling is another approach to predicting the likely impacts of climate change on cotton production in the future (Matthews *et al.,* 2002). COTCO2 model is capable of predicting cotton crop responses to elevated atmospheric CO_2concentrations and potential concomitant changing climate variables. Here, the major plants processes are known to be influenced by CO_2 are simulated explicitly that is photosynthesis, photorespiration, and stomatal conductance, and its role in leaf energy balance. The model explicitly simulates the impact of atmospheric CO_2 concentration on C3 photosynthesis and photorespiration at the level of carboxylation and oxygenation. Growth is simulated for individual organs, such as leaf blade, stem segment, taproot and lateral roots, and fruit, which include squares and bolls. Potential growth is calculated and the carbohydrate and nitrogen required to meet this potential are calculated. Actual growth is based on substrate availability, the potential growth, and water stress. Simulations suggest that if warming is accompanied by higher humidity, the impact of climate change may be minimal. However, if the climate becomes warmer and less humid, ET may increase substantially. Simulations also suggest that enhanced growth due to elevated CO_2 may have a greater impact on ET than climatic change (Zeng and Heilman 1997; Sankaranarayanan *et al.*, 2010).

Tasks ahead : The impact of elevated CO_2 and global climatic changes will have profound effect on agriculture through direct and indirect effects on crops, both through biotic and abiotic routes. Besides ameliorating global climate change through biophysical means (for reduction in emission of greenhouse gases), the issues concerning the global climate change can be tackled to some extent by crop adaptation strategies. CO_2 elevation and associated changes



(Fig. Source: Reproduced from Reddy *et al.*, 2010. CURRENT SCIENCE, VOL. 99 (1), JULY 2010) are taking place gradually, plants may get adapted to these changes (Hebbar *et al.*, 2007). Rainwater management technologies would play a greater role in rainfed cotton cultivation to mitigate the effect of higher ET by ever increasing temperature and changing pattern of precipitation. By adopting altered date of planting, selection of heat and drought tolerant genotypes, improved land use and natural resource management policies, improved risk management strategies like early warning system and crop insurance and approaches to increase soil carbon, such as, organic manures, minimum tillage, residue management and integrated pest/weed management should be encouraged to reduce the impact of climate change.

Reddy *et al.,* (2010) clearly indicated that increased or decreased biomass yields in plants grown under elevated CO_2 would certainly depend upon the source–sink balance which in turn would be associated with changes in activities of key photosynthetic enzymes and the expression of photosynthetic genes. The morphological, physiological, biochemical and molecular responses of different plants to elevated CO_2 suggests that photosynthetic acclimation and the resulting down-regulation of plant metabolism is due to imbalances between the source sink capacity. Future genetic studies on sugar management for biomass production in green plants, exposed to increased CO_2 concentration in the atmosphere shall be essential (Reddy *et al.*, 2010). Genetic transformation of plants for efficient nitrogen assimilation under elevated CO_2 is also suggested in improving the capacity of nitrogen sink to mitigate excessive accumulated sugars. It would also be useful to understand the impact of elevated CO_2 on primary photosynthetic reactions including photosystem II photochemical performance. Reddy *et al.,* (2010) have also suggested that genetic manipulation of crop plants for positive acclimatory responses is an extremely useful strategy to obtain optimal crop yields under predicted changing global climate.

The interactive relationships of the environmental variables like temperature, radiation, water availability, visible and ultraviolet sunlight, salinity, soil nutrition etc., complicate the predictability of consequences of rising CO_2 in atmosphere (Reddy *et al.,* 2010) . Therefore, the interactive effects of multiple environmental factors on plant responses to rising CO_2 require a careful study. Such

Table 2. Effect of water stress and elevated CO_2 atmosphere on morphological attributes of cotton

Character	Elevated CO_2		Ambient CO_2		CD at
	Unstressed	Stressed	Unstressed	Stressed	(p=0.05)
Plant height (cm)	45.2	38.3	37.6	29.7	2.8
Sympodia number	17.8	17.2	17.4	16.0	NS
Node number	21.4	20.0	20.8	18.2	0.7
Leaf number	64.6	52.0	54.4	48.2	3.2
Boll number	13.8	11.8	10.6	6.6	0.6
Single boll weight (g)	2.08	1.97	1.88	1.76	0.31
Yield (g) /plant	27.4	23.2	20.0	11.6	1.5
Total biomass (g)/plant	83.5	69.0	61.7	39.4	2.8
Harvest index	32.7	33.5	32.3	29.5	1.9

Adopted from Khader *et al.*, (2004)

information should demonstrate how the multiple environmental factors, when altered in a changed climate, could interact with each other resulting in increase or decrease in the growth and metabolism of several plants. Optimization of sustainable and natural fertilizing sources including nitrogen fixing crop rotations, compost, composted manures in cotton production have been suggested for adaptation to climate change (Ton, 2012).

Hake (2012) has suggested further research into adaptation aspects like stress tolerance traits and germplasm, fibre yield enhancement, nitrogen use efficiency, site specific monitoring and input management, phenotypic breeding for elevated CO_2 environments and innovations in fibre quality.

Since climate plays a major and critical role in all the bio activities involving crops, animal and microbes, a concerted effort is needed in forecasting the likely affected parameters of climate change, its probable impacts and its mitigation strategies for fulfilling the cherished goals of sustainable agriculture, particularly a commercial crop like Cotton, and uninterrupted growth/progress of all the stakeholders.

REFERENCES

Aggarwal, P. K. 2008. Global climate change and Indian agriculture impacts, adaptation and mitigation. *The Indian Journal of Agricultural Sciences* **78 :** 911-09.

Ahuja, I., de Vos, R.C., Bones, A.M and Hall, R.D. 2010. Plant molecular stress responses face climate change. *Trends Plant Sci.* **15:**664–74.

Berry, J.O., Yerramsetty, P., Zielinski, A.M., Mure, C.M. 2013. Photosynthetic gene expression in higher plants. *Photosynth. Res.*, doi:10.1007/s11120-013-9880-8.

Bhattacharya, N. C., Radin, J. W., Kimball, B. A., Mauney, J. R., Hendrey, G. R., Nagy, J., Lewin, K. F. and Ponce, D. C. 1994. Leaf water relations of cotton in a free air CO_2 enriched environment. *Agricultural Forest Meteorology* **70 :** 171-82.

Blankenburg, M., Haberland, L., Elvers, H.D., Tannert, C. and Jandrig, B. 2009. High-throughput omics technologies: Potential tools for the investigation of influences of EMF on biological systems. *Curr. Genom.* **10 :** 86–92.

Bowes, G. 1991. Growth at elevated CO_2. Photosynthesis responses mediated through RuBisCO. *Plant Cell Environ.* **14 :** 795–806.

Chaves, M.M., Flexas, J. and Pinheiro, C. 2009. Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. *Ann. Bot.*, **103 :** 551–60.

Dugas, W. A., Heuer, M. L., Hunsaker, D., Kimball B. A., Lewin, K. F., Nagy, J. and Johnson M. 1994. Sap flow measurements of transpiration from cotton grown under ambient and enriched CO2 concentrations. *Agricultural Forest Meteorology*, **70 :** 231-45.

Eberhard, S., Finazzi, G. and Wollman, F. A. 2008. The dynamics of photosynthesis. *Annu. Rev. Genet.* **42 :** 463–515.

FAO, 2000. Two essays on climate change and agriculture-a developing country perspective. *FAO Economic and social development paper* 145. FAO, Rome.

Foyer, C.H., Neukermans, J., Queval, G., Noctor, G. and Harbinson, J. 2012. Photosynthetic control of electron transport and the regulation of gene expression. *J. Exp. Bot.*, **63 :** 1637–61.

Gupta, B., Sengupta, A., Saha, J. and Gupta, K. 2013. Plant abiotic stress: 'Omics' approach. *J. Plant Biochem. Physiol.*, **1 :** e108.

Hebbar, K. B., Venugopalan, M. V., Khadi, B. M. and Aggarwal, P. K. 2007. Impact from climate change on cotton production (abstracts). National Conference on *"Impact of Climate Change with Particular Reference to Agriculture"* organised by Agro-Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, during 22 – 24, August.

Hendrix, D. L., Mauney, J. R., Kimball, B. A. Lewin, K., Nagy, J. and Hendrey, G. R. 1994. Influence of elevated CO_2 and mild water-stress on nonstructural carbohydrates in field-grown cotton tissues. *Agricultural Forest Meteorology* **70 :** 153-62.

Hileman, D. R., Huluka, G., Kenjige, P. K., Sinha N., Bhattacharya, N. C., Biswas, P. K., Lewin, K. F., Nagy, J. and Hendrey, G. R. 1994. Canopy photosynthesis and transpiration of field-grown cotton exposed to free-air CO_2 enrichment (FACE) and differential irrigation. *Agricultural Forest Meteorology* **70 :** 189-207.

Hippler, M., Klein, J., Fink, A., Allinger, T. and Hoerth, P. 2001. Towards functional proteomics of membrane protein complexes: Analysis of thylakoid membranes from *Chlamydomonas reinhardtii. Plant J.* **28 :** 595–606.

Hogan, K. P., Smith, A. P. and Ziska, L. H. 1991. Potential effects of elevated CO^2 and changes in temperature on tropical plants. *Plant Cell and Environment* **14 :** 763-78.

Huluka G, Hileman D R, Biswas P K, Lewin K F, Nagy J and Hendrey G R.1994. Effects of elevated CO_2 and water-stress on mineral concentration of cotton. *Agricultural Forest Meteorology* **70 :** 141-52.

Hunsaker, D. J., Hendrey, G. R., Kimball, B. A., Lewin, K. F., Mauney, J. R. and Nagy, J. 1994. Cotton evapotranspiration under field conditions with CO_2 enrichment and variable soil-moisture regimes. *Agricultural Forest Meteorology* **70 :** 247-58.

IPCC, 2007. Climate Change 2007, the Physical Science Basis. Summary for policy makers. Report of Working Group I of the Intergovernmental Panel on Climate Change. http://www.ipcc-wg1.unibe.ch/publications/wg1-ar4/wg1-ar4.html.

Johns, C. V. and Hugher, L. 2002. Interactive effects of elevated CO2 and temperature on the leaf-miner Dialectica scalariella Zeller (Lepidoptera, Gracillariidae) in Paterson's Curse, Echium plantagineum (Boraginaceae). *Global Change Biology* **8 :** 142–52.

Khader , SESA, Gopalakrishnan, N., Prakash, A. H. and Rajendran, T. P. 2004. Elevated CO_2 induced tolerance to moisture stress in cotton. International symposium on *"Strategies for sustainable cotton production-A Global Vision",* organised by University of Agricultural Sciences, Dharwad and Indian Council of Agricultural Research, New Delhi during 23-25, November.

Kramer, P.J. 1981. Carbon dioxide concentration, photosynthesis, and dry matter production. *Bioscience* **31 :** 29–33.

Maayan, I., Shaya, F., Ratner, K., Mani, Y., Lavee, S., Avidan, B., Shahak, Y. and Ostersetzer-Biran, O. 2008. Photosynthetic activity during olive (*Olea europaea*) leaf development correlates with plastid biogenesis and RuBisCO levels. *Physiol. Plant.*, **134 :** 547–58.

Matthews, R., Stephans, W., Hess, T., Middleton T. and Graves, A. 2002. Application of crop soil simulation model in tropical agricultural system. *Advances Agronomy* **76 :** 31-124.

Mattson, W. J. 1980. Herbivory in relation to plant nitrogen content. *Ann. Rev. Ecology Systematics* **11 :** 119–61.

Mauney, J. R., Kimball, B. A., Pinter, P. J., LaMorte, R. L., Lewin, K. F., Nagy, J. and Hendrey, G. R. 1994. Growth and yield of cotton in response to a free air carbon dioxide enrichment (FACE) environment. *Agricultural Forest Meteorology* **70 :** 49-67.

Nagy, J. and Hendrey, G. R. 1994. Growth and yield of cotton in response to a free-air carbon-dioxide enrichment (FACE) environment. *Agricultural Forest Meteorology* **70:**49-67.

Nakayama, F. S., Huluka, G., Kimball, B. A., Lewin K. F., Nagy, J. and Hendrey, G. R. 1994. Soil carbon-dioxide fluxes in natural and CO_2 enriched systems.*Agricultural Forest Meteorology* **70 :** 131-40.

Nouri , M.Z., Moumeni, A. and Komatsu, S. 2015. Abiotic Stresses: Insight into Gene Regulation and Protein Expression in Photosynthetic Pathways of Plants. *Int. J. Mol. Sci.* 2015, **16 :** 20392-416.

Nouri, M.Z. and Komatsu, S. 2013. Subcellular protein overexpression to develop abiotic stress tolerant plants. *Front. Plant Sci.*, **4 :** 2.

Pego, J.V., Kortstee, A.J., Huijser, C. and Smeekens, S.C.M. 2000. Photosynthesis, sugars and the regulation of gene expression. *J. Exp. Bot.*, **51 :** 407–16.

Pettigrew, T W. 2007. High temperature effects on cotton yield, yield components, and fibre quality. Back to *“The ASA-CSSA-SSSA International Annual Meetings”*, November 4-8, New Orleans,Louisiana

Pinheiro, C., Chaves, M.M. Photosynthesis and drought 2011. Can we make metabolic connections from available data? *J. Exp. Bot.* **62 :** 869–82.

Prins, A., Mukubi, J.M., Pellny, T.K., Verrier, P.J., Beyene, G., Lopes, M.S., Emami, K., Treumann, A., Lelarge-Trouverie, C. and Noctor, G. 2011. Acclimation to high CO2 in maize is related to water status and dependent on leaf rank. *Plant Cell Environ.* **34 :** 314–31.

Printer, P. J., Idso, S. B., Hendrix, D. L., Rokey, R. R., Rauschkolb, R. S., Mauney, J. R., Kimball, B. A., Hendrey, G. R., Lewin, K. F. and Nagy, J. 1994. Effect of free-air CO_2 enrichment on the chlorophyll content of cotton leaves. *Agricultural Forest Meteorology* **70 :** 163-69.

Prior, S. A., Rogers, H. H., Runion, G. B. and Hendrey, G. R. 1994. Free-air CO_2 enrichment of cotton - vertical and lateral root distribution patterns. *Plant Soil* **165 :** 33-44.

Prior, S. A., Rogers, H. H., Runion, G. B., Kimball, B. A., Mauney, J. R., Lewin, K. F., Nagy, J. and Hendrey, G. R. 1995. Free-air carbon dioxide enrichment of cotton-root morphological characteristics. *Jour. Environ. Quality* **24 :** 678-83.

Prior, S. A., Torbert, H. A., Runion, G. B., Mullins G. L., Rogers, H. H. and Mauney, J. R. 1998. Effects of carbon dioxide enrichment on cotton nutrient dynamics. *Jour. Plant Nut.* **21 :** 1407-26.

Radin, J W. 1992. Reconciling water use efficiencies of cotton in field and laboratory. *Crop Sci.* **32 :** 13–8.

Reddy, K.R., Hodges H F and Reddy V R.1992. Temperature effects on cotton fruit retention. *Agron. Jour.* **84 :** 26-30.

Reddy, K.R., Harry F. Hodges and McKinion J. M. 1995. Carbon dioxide and temperature effects on pima cotton development. *Agron. Jour.* **87 :** 820-26.

Reddy, K.R., G.H. Davidonis, A.S. Johnson, and B.T. Vinyard. 1999. Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. *Agron. J.* **91 :** 851–58.

Reddy, K.R., Koti, S., Davidonis, G.H. and Reddy, V.R., 2004. Interactive effects of carbon dioxide and nitrogen nutrition on cotton growth, development, yield and fiber quality. *Agron. J.* **96 :** 1148–57.

Ramakrishna, Y. S., Rao, G. G. S. N., Srinivas, Rao G. and Vijay Kumar, P. 2006. Climate change. (in)*Environment and Agriculture* pp.1-30 Chada K.L. and Swaminathan M.S. (Eds.). Malhotra Publishing House, New Delhi.

Reddy, V. R., Reddy, K. R. and Cock, A. 1994. Carbon dioxide and temperature effects on cotton leaf initiation and development. *Biotronics* **23 :** 59-74.

Reddy, A. R., Girish K. Rasineni and Agepati S. Raghavendra 2010. The impact of global elevated CO_2 concentration on photosynthesis and plant productivity. *Curr. Sci.* **99 :** 46–57.

Rosenzeveig, C and Parry, M. 1994. Potential impact of climate change on world food supply. *Nature* **367 :** 133-38.

Sankaranarayanan, K., Praharaj, C. S., Nalayini, P., Bandyopadhyay K. K. and Gopalakrishnan, N. 2010. Climate change and its impact on cotton. *Ind. Jour. Agri. Sci.* **80 :** 561-75,

Taiz, L. and Zeiger, E. 2010. *Plant Physiology*, 5th ed.,Sinauer Associates: Sunderland, MA, USA.

Ton, P. 2012. Cotton and climate change: Impacts and Options to mitigate and adapt. *Cotton Res. J.* 142-159.

Torbert, H. A., Prior, S. A., and Rogers, H. H. 1995. Elevated atmospheric carbon-dioxide effects on cotton plant residue decomposition. *Soil Science Society of America Journal* **59 :** 1321-28.

Wall, G. W., Amthor, J. S, and Kimball B A.1994. $COTCO_2$ - a cotton growth simulation-model for global change. *Agricultural Forest Meteorology* **70 :** 289-342.

Wong, S C.1993. Interaction between elevated atmospheric concentration of CO_2 and humidity on plant growth-comparison between cotton and radish. *Vegetation* **104 :** 211-21.

Wood, C. W., Torbert, H. A., Rogers, H. H., Runion, G. B. and Prior, S. A. 1994. Free-air CO_2 enrichment effects on soil carbon and nitrogen. *Agricultural Forest Meteorology* **70 :** 103-16.

Woodson, J.D. and Chory, J. 2008. Coordination of gene expression between organellar and nuclear genomes. *Nat. Rev. Genet.* **9:**383–95.

Yin J, Sun Y, Wu G and Ge F. 2010. Effects of elevated CO_2 associated with maize on multiple generations of the cotton bollworm, *Helicoverpa armigera.Entomologia Experimentalis et Applicata* **136 :** 12-20.

Zeng, W. and Heilman, J. L. 1997. Sensitivity of evapotranspiration of cotton and sorghum in west Texas to changes in climate and CO_2. *Theoretical Applied Climatology* **57 :** 245-54.

Zhao, D., Reddy, K. R., Kakani, V. G., Mohammed, A. R., Read, J. J. and Gao, W. 2004. Leaf canopy photosynthetic characteristics of cotton under elevated CO2 concentrations and UV-B radiation. *Jour. Plant Phy.* **161 :** 581-90.

3

Cotton and its prospective uses

NIRMAL YADAV AND VANDANA GUPTA

Department of Textile and Apparel Designing, CCS Haryana Agricultural University, Hisar-125 004

E-mail: nirmal404@gmail.com

ABSTRACT : Consumers worldwide are becoming aware of natural fibers and slowly but steadily the trend is again shifting to better natural products. Cotton is a natural fiber bestowed with special properties which includes hypo-allergic, soft hand, can be blended with other fiber and many more. Cotton plays an important role in the Indian economy as the country's textile industry is predominantly cotton based. Products developed with the cotton fibers can pave the way to stay ahead in the competition wherein the demand for organic and natural fiber products may even surpass that of synthetic fibers. The innovative ideas and quality functional finishes imparted to cotton fabric and cotton based products would help the growth of cotton in different sectors. Apart from wide use in textiles for clothing, cotton textiles are rapidly capturing the market. Nonwoven, composites, blends made from cotton fabrics are being used for medtech, sportech, hometech, with better performance properties.

Key words : Cotton, Functional properties, Performance uses, Recyclable cotton products

From blue jeans to baby wipes, from dollar bills to dynamite, cotton is more than just the fabric of our lives. Cotton is a natural fiber that comes from the seedpod of the cotton plant. It is a warm climate crop and is mainly grown between 37^0 N and 32^0 S. The northern hemisphere accounts for about 90 percent of global cotton production(International Trade Centre). Cotton has been cultivated and fashioned into fabrics for at least 7,000 years. Archeologist have found cotton fabric fragments in Mexico dating to 3,500 B.C., India to 3,000 B.C., and in the southwestern United States to 500 B.CNot only, all parts of the cotton plant economically useful, but the multitude of uses it can be put to, makes it India's one of the value-added crop. When we think of cotton there is an immediate association with apparel, but there is so much more. An example is paper currency, which is made of 75 percent of cotton and 25 percent of linen. Industrial products containing cotton includes wall covering, book binding, zippers, thread, cotton clothwhile the short fuzzy linters provide cellulose for making plastics, explosives, paper products, paddy for furniture and cotton balls. Linters with longer fibers are used for medical suppliers, twine, candle wicks (Wright, 2003). The cotton seed is crushed to produce oil for salad dressing, and the meal and hulls became animal feed. The stalks and leaves are ploughed to enrich the soil. Cotton is so versatile, just about everything one's wear has the potential of cotton being used, from hats to shoes, jeans to shirt (Cotton Incorporated, 2010).

Cotton and Indian textile industry : The Indian textiles industry is extremely varied, with the hand-spun and hand-woven textiles sectors at one end of the spectrum, while the capital intensive sophisticated mills sector at the other end of the spectrum. The decentralized power looms/ hosiery and knitting sector form the largest component of the textiles sector. The close linkage of the textile industry to agriculture (for raw materials such as cotton) and the ancient culture and traditions of the country in terms of textiles makes the Indian textiles sector unique in comparison to the industries of other countries. The Indian textile industry has the capacity to produce a wide variety of products suitable to different market segments, both within India and across the world (Anonymous, 2015).

Cotton plays an important role in the Indian economy as the country's textile industry is predominantly cotton based. India is one of the largest producers as well as exporters of cotton yarn. The states of Gujarat, Maharashtra, Andhra Pradesh (AP), Haryana, Punjab, Madhya Pradesh (MP), Rajasthan, Karnataka and Tamil Nadu (TN) are the major cotton producers in India. The Indian textile industry contributes about 11 percent to industrial production, 14 per cent to the manufacturing sector, 4 percent to the GDP and 12 per cent to the country's total export earnings. India is also the second largest producer of cotton worldwide. In India during 2013-2014, cotton yarn production increased by two per cent and cloth production from mill and power loom sector increased by 5 per cent and 6 per cent, respectively. Readymade garments were the largest contributor to total textile and apparel exports from India in FY15. Cotton and man made textiles was also major contributor with shares of 31 per cent and 16 per cent, respectively. China is the biggest importer of raw cotton from India. The other major cotton importing countries from India are Bangladesh, Egypt, Taiwan, Hong Kong.Various reputed foreign retailers and brands such as Carrefour, Gap, H&M, JC Penney, Levi Strauss, Macy's, Marks & Spencer, Metro Group, Nike, Reebok, Tommy Hilfiger and Wal-Mart import Indian textile products.(Indian Brand Equity Foundation, 2015 and Anonymous, 2015)

Consumer and their choices for cotton products With the advent of synthetic fibers during the last few decades, it was felt that the natural fibers would be in oblivion. But the demand for cotton remains high because of its suitability on the basis of price, quality and comfort, across a wide range of textile products. Studies reveal that preference for cotton productsand its role in textile and apparel is high among all demographic segments. The majority of Mexican consumers (75%) prefer clothing made of cotton due to its comfort properties. Japanese consumers relate quality to fiber: 80 per cent prefer that clothing they wear the most be made of cotton and cotton blends. Whereas majority of U.S. consumers prefer casual wear like jeans (95%), socks (94%), business wear like dress shirts (79%) and dress parts (63%), athletic wear (71%) and home textile items like bath towels (90%) and sheets (81%) to be made from cotton and cotton blends. Their positive associate with cotton includes comfort, soft, good quality, durable, natural, fashionable and sustainable. (Cotton Incorporated. 2010; Cotton Incorporated 2013)

Functional finishes on cotton : Reforming to compete : It is well known that cotton possesses the unique combination of properties like comfort, handle, absorbency, wicking, and have traditional uses such as apparels, home textiles and many more. With increasing consumer demand for cotton based products and to compete with synthetic fiber based materials, the textile and apparel industry as well as suppliers are making strong efforts to improve the functional properties of textile materials such as cotton by using nanotechnology, which deals with the science and technology at dimension of roughly 1 to 100 nanometers (Srivasramakrishnan, 2015), microencapsulation technology; which is a technique by which solid, liquid or gaseous active ingredients are packaged within a second material for the purpose of shielding the active ingredient from the surrounding environment. Thus the active ingredient is designated as the core material whereas the surrounding material forms the shell (Dubey, 2009).Another buzz word in this 21st century is the smart materials such as phase change, shape memory materials and conductive materials, which are used to develop next generation cotton based fabrics that can complement the advantages of cotton and man-made fibers. Some functional properties imparted to cotton textiles includes:

Fire proof (flame resistant) apparel, which is suitable for professional uses and provides effective protection against potential risk associated with high temperature and particularly flashover, flash fire, welding exposures. One such example is UltraSoft® fabric, designed with both comfort and safety in mind. It is created with a unique blend of 88 percent cotton and 12 per cent high tenacity nylon to provide soft feel for greater comfort, enhanced wear life and protective performance. In fact, the fabric is engineered to focus the excellent abrasion resistance of the nylon on the outer surface to prolong garment wear life, while the cotton fibers are focused towards the skin to optimize comfort. (http://www.westex.com/fr-fabric-brands/ultrasoft/)

Temperature management: Outlast® fabric line is other advancement, as this technology is designed to provide comfort by regulating the temperature next to the skin, based on environmental conditions. Temperature regulation is achieved by: phase change technology, which is based on a cyclic process in which latent heat is absorbed, stored and released by the encapsulated particles such as silver based finishes (SilverSmat®), as they change from solid to liquid phases or vice versa. This technology is used to produce hosiery products, footwear by Nike, men's shirt with outlast technology is sold at Jos as well as home textile products such as pillows, mattress-tickling fibers, mattress pads, woven blankets made from cotton fibers. (http://www.outlast.com/en/technology/)

Moisture management: Wicking Windows™ is a unique moisture management application for cotton that eliminates the feeling of wet, saturated fabric against the body. Cotton fabrics generally wick well and typically absorb much more moisture than synthetic fibers. During exercise, many fabrics can become overly saturated with perspiration. As the body moves, most wet fabric tends to cling to the skin, irritate or chafing can occur. The Window Wicking™technique transfer the moisture away from the skin to the outer of the fabric, where it can evaporate, keeping the wearer drier and more comfortable. Another technology which transfers moisture and dries faster is TransDRY®. This technology begins by treating cotton yarn's with a special process to make them water repellent and provide better performance than polyester and nylon. The technology provides effective moisture management performance in a variety of product categories including woven shirting, bottom weight fabrics, denim and socks. (Crumbley, Cotton incorporated)

Water repellent: Many water-repellent treatments inhibit a fabric's ability to breathe and transfer moisture vapor effectively. STORM COTTON™ technology does not affect the natural ability of cotton fabrics to breathe.. Although it repels liquids, the finish still allows moisture vapor to pass through the fabric where it can dissipate into the environment, naturally keeping the wearer more comfortable. Since the STORM COTTON™ technology minimizes the amount of water the fabric will hold, garments dry much faster than untreated cotton, minimizing the amount of time and energy required for laundering. The STORM DENIM™ is another technology of water repellent finish which is applied in garment form thus allows for greater flexibility to apply various garment finishing techniques to achieve the desired styling and appearance of the finished product (Cotton Incorporated)

Self cleaning: New Teflon™ fabric protector Shield and Clean Portfolio is advanced care for a better planet. In apparel, Teflon™ fabric protector fends off soil, stains and spills on wool, cotton, and blends without impacting the fabric's weight, look, feel, color or breathability. Indoors Teflon™ fabric protector makes it easier to keep upholstery, draperies, bedding and linens looking fresh and clean. Outdoors, Teflon™ fabric protector provides continuous protection for awnings and patio furniture cushions (Chremours).

Antibacterial finish: The demand for antimicrobial fibres, fabrics and apparel has increased sharply since the mid-1990s due to growing awareness among consumers due to the importance of personal hygiene and the health risks posed by certain microorganisms. As a result, there is new generation of antimicrobial products on the market which offer protection against a broad spectrum of bacteria and can withstand up to 100 launderings. A good example of the work being done in this area is DuPont's Biowear® materials for protection against bloodborne pathogens. Sol-gel methods have been successfully employed to impart oil/water repellency and anti-bacterial capability to cotton using fluorocarbon polymer/SiO2 and silver nanoparticle-doped silica hybrid materials, respectively(Tarimala*et al.,* 2006;Yeh*et al.,*2007).

Wrinkle resistant: Nowadays aesthetic aspects have an increasing influence on the overall quality of a garment. Fabric appearance is usually characterized by a number of factors such as strength, pilling, abrasion resistance, shrinkage, drape, color and wrinkles. Cotton with all its positive attributes has one major disadvantage of being wrinkles. Studies reveals that this problem can be solved by introducing shape memory materials in textiles. These are the new class of material which has the potential to remember a pre programmed shape, which can help the fabrics to remove wrinkles without being ironed (Gupta *et al.,* 2014).Vasile *et al.*, 2010 conducted a study to develop fabric with body temperature SMA (Shape Memory Alloys) wires embedded in 100 per cent cotton fabric. Shape memory polymers are also reported to impart wrinkle free, shrink resistance, easy to wash quality and good chemical resistance to cellulosic fabrics such as cotton , ramie, linen.

Cotton as conductors: At the Textiles Nanotechnology Center at Cornell University, Professor Juan Hinestroza and a team of researchers have given cotton threads special properties using nanotechnology. The cotton fibers are covered with microscopic particles enabling them to conduct electricity. The applications of this are endless, but they have already used them to sense the heart rate of a person wearing the fabric(Cattermole, 2010)

Sustainable and recyclable cotton products : Organic cotton is the buzz word in today's sustainable environment. Organic cotton clothing, unheard of a few years ago, is now available in many stores and online businesses. Apparel companies are developing programs that either use 100 per cent organically grown cotton, or blend small percentages of organic cotton with conventional cotton in their products. There are a number of companies such as Esquel and Patagonia driving the expanded use of domestic and international organic cotton, thus responding to market requirements for organic products such as sportswear, personal care items, home furnishing, children products(Shishoo, 2015).Indian brands and companies working in manufacturing and retailing of organic cotton textile and garments includes UV and W the company belongs to the Venus Group from Ludhiana, Punjab and is the first in India to engage in the marketing of certified Organic cotton clothing. Other includes Anokhi, one of the oldest brands in market and an expert in block printing with vegetable colour dyes. Bhu:sattva is as connected to the Earth as its name. With an idea to inculcate ethics and sustainability in the entire supply chain, and, thus, ensuring a Fair Trade Concept(Ayala, 2014). Organically grown, naturally colored cotton is also receiving increasing importance due to their eco-friendly character and range from dark tan, brown, khaki, grey and green(Kranthi, 2014).

Recyclable branded accessories and apparel: Eco Smart by Hanes, one of the oldest branded clothing, is the well known trade mark for fibers made with recycled contents. Eco Smart men's black athletic socks contain at least 55 per cent recycled cotton fibers, and the white socks are produced with 15 per cent yarn content. Puma's Bring Me Back program has a great role in the recycling process. Puma's InCycle is a sustainable collection that includes shoes, apparel, accessories and home insulation materials made either by biodegradable polymers or recycled polyester and organic cotton. Biodegradable lifestyle sneaker developed by Puma is made up of blend of organic cotton and linen and sole comprises biodegradable plastic APINAT Bio, which is biodegradable when disposed of correctly. 100 per cent organic denim is made by Volcom with ozone bleaching and laser finishing to reduce environmental impacts caused by conventional chemicals and auxilarries (Muthu, 2014).

Future of cotton in different sectors : Cotton is playing a very important role in the traditional textile and apparel industry but is not restricted to such uses in recent time. The horizon of cotton products have increased due to the advances made and functional finishes added to cotton based materials to improve as well as enhance its performance properties. Technical textiles are the fastest growing area of textile consumption in the world. As per the market survey it has projected an average growth rate of 4 per cent for technical textiles during the period 1995-2005 (Gopalakrishnan). Technical Textiles is a high technology sunrise sector which is steadily gaining ground in India. Technical textiles are functional fabrics that have applications across various industries including automobiles, civil engineering and construction, agriculture, healthcare, industrial safety, personal protection etc. (Anonymous, 2015)All kinds of fibers such as natural (cotton, silk, coir, jute and wool, kenaf), man-made fibers (viscose, polyester, nylon, acrylic etc.) as well as high performance specialty fibers find their usage in technical textiles with more percentage of man-made fibers due to their inherent advantage of having higher strength and versatility. The current use of cotton in Indian technical textile industry is 6.8 percent. With new advances and its eco-friendly properties of cotton as compared to synthetics will find its way for different applications.T Rajkumar chairman of Southern India Mills Association (SIMA) said that industrialist involved in technical textiles should look forward to invest in cotton based technical textiles as, India produces nearly 39 million bales of cotton every year, and cotton industry is the backbone of the textile sector. Also, around 70 per cent of technical textiles require man-made fiber and filaments and the cost of these fibers and filaments in India is around 20-30 per cent higher, as compared to China and Indonesia (Anonymous, 2014).Different segments were cotton based products are used and exhibit a potential of increasing market demand are listed as:

Sporttech: With increasing worldwide interest and participation in active sports and outer leisure pursuits have resulted in strong historical growth in the consumption of textile materials in sporting and related goods and equipments**.** Sportswear includes apparels with performance enhancement characteristics (moisture management, comfort, elastomeric, soil guard, anti-microbial) as well as sports goods like inflatable ball and sports accessories;astro-turfs, nets rings etc. **(**Shishoo, 2005).Cotton or poly/cotton fabrics find its place in the production of sleeping bags as inner fabric,organic cotton is used primarily throughout canvas shoes and also children shoes. Pure cotton canvas and polyester cotton blended canvas (polyester/cotton 30/70 or 50/50) are the widely used material for making tents.T-shirts, swimsuits and bikinis made entirely from cotton or cotton blends are becoming popular. (ICRA Management Consulting Services. 2010)

Hometech: The fabrics used in home textiles control interior environment of home. Natural fibers such as cotton, wool, linen, etc., are dominant in the home textiles sector with some of the manmade fibers which includes rayon, nylon, polyester, Teflon etc. The share of cotton and man-made fibers, in the production of home textilesaccount for around 38 per cent and 37 per cent respectively.(Anonymous, 2009). Blends of natural and synthetic fibers have also attracted attention of home textile manufacturers to enhance the fabric performance (Das, 2010).Home textiles includes curtain fabric and draperies which are made with solid color plain weave materials in cotton, flax, wool, silk acrylic etc. Blinds, a type of window textile is usually made up of cotton fabric which gives 100 per cent opacity. Sheets and pillowcases materials normally used are 100 percent carded cotton, ring-spun yarn or open end yarn.. Cotton terry blankets (CBI Market Survey, 2008)bedspreads, mattress covers in traditional jacquard patterns are made up of cotton. Towels made of blends like bamboo and cotton, soy and cotton (Soycot®) exhibit better soft as well as absorbency. Milk fiber obtained from cow's milk by using new bioengineering technology is being blended with cotton to regulate the air quality and exhibits properties like soft, brilliant, antibacterial, absorbent and humectants, thus having great potential for household and spa towels, bathrobes, bed linen and bedspreads (Das, 2010).

Medical applications: Cotton is majorly used in the manufacture of Medtech nonwoven products due to its highly absorbent nature. It is naturally breathing; it has good aesthetic characteristics, keeps dimensional stability and strength even at high temperatures. The use of nonwoven cotton fabric is for hygiene products, which includes disposable diapers, baby wipes, feminine hygiene products, training pants: wipes such as industrial wipes, surgical wipes: medical includes sponges, dressing , contamination control gowns, incubator mattresses, heat packs. Five percent of the Indian technical textiles market comprises medtech applications. Of this, nearly 35 per cent goes into sanitary napkins, healthcare and hygiene products, another 30% comprises surgical dressings and sutures represent around 20 per cent. Medtech also includes diapers and orthopaedic implants (Anonymous, 2006).The most frequently used biotextile, especially in the process of surgery, sutures help close the wound, a function that will last for a relatively long time until the natural healing process is restored to provide a sufficient level of wound strength. Natural materials, including flax, hair, cotton, silk and catgut, had been used for this purpose in many centuries. Wound dressing is another important application where cotton is being used to treat different types of wounds. In line with the vapour transmission rate of the dressings, non-occlusive dressings, mostly based on woven cotton gauze, allow water vapor and fluid to freely transmit into and out of the wound(Zhong, 2012).

Mobiltech: The application of natural fibers in the automotive industry as interior components has been developed since 1995, primarily in Europe. Natural fibers such as cotton, flax, kenaf, and their blends have been explored to develop products that can go into automobiles and find their application in interior parts such as trunkliners, headliners, carpet backings, dashboards, acoustic insulation and absorbent materials.Shift towards the use of natural fibers is due to the new European directive, by 2011, over 95 per cent automobiles should be recyclable (Ramkumar,S)and to reduce weight of automobiles as a small solution to improve the fuel efficiency and help the global warming issue. It was found that the automotive nonwoven developed by using kenaf fiber blended with cotton fibers, recycled polyester and off-quality polypropylene could meet industry specifications of flammability, noise absorbent, odor, biodegradability as well as strength properties (Zhang, 2004).A trans-atlantic alliance involving University of Tennessee-Knoxville, USDA-SRRC and the University of Bermen, Germany has been working towards cotton composites for automotive applications and found that intimately blended cotton fibers with binder fibers gave better composite and revealed that cotton can form a good substitute for synthetics. (Ramkumar, S)

Other sectors includes

Agrotech: These are the Agro-textiles, also known as Agrotex, that are used in agricultural applications related to growing and harvesting of crops and animals.Mulch & Seed Innovation in Centre, Alabama, is turning the by-product from cotton ginning into high-quality mulch. While most other mulch is made from virgin trees, this mulch is made using cotton gin "trash." The result is reduced waste going to landfills, and mulch production turning into a green industry itself.(Cattermole, 2010)

Geotech: Natural fibers such as jute, cotton, flax are also finding increasing application, particularly in Asian countries (Reddi, 2003). One such example is the production of reinforced composites by using blend of cotton, flax and recycled polypropylene.(Foulk *et al.,* 2006**).** In erosion control where the short life span of the geofabric is an advantageous property, natural fiber such as jute and coir are used to control erosion of hill slopes and embankment slopes. Cotton fiber perhaps can be tried in this area provided the property of the fabric is engineered to the specific end use.(Rakshit *et al.*, 1994)

Buildtech: Buildtech segment comprises of textiles or composite materials used in the construction of permanent and temporary buildings as well as structures. Textiles are used in construction for concrete reinforcement, façade foundations systems, interior construction, insulations, proofing materials, air conditioning, noise prevention, protection, visual protection, protection against the sun building safety (Anonymous, 2013).Thin composite boards have been manufactured with the noils obtained from the cotton combing process, blow room waste, and polyester resin at room temperature utilizing a compression method. Such composite boards made by using cotton waste show the potential to replace wood and fiber products as the thin boardsfor furniture and interior(Zhang 2004).

Packtech: It includes several flexible packing material made of textile used for packing various goods for industrial, agricultural, consumer and other goods. It ranges from polymer based bags used for industrial packing to jute based sacks used for packaging food grains and packaging used for tea. Cotton is mostly used for wrapping fabric made out of HDPE/PP and cotton canvas. (textilelearner.blogspot.in/2013/01/packtech-textile-packaging-material.htm)

Protech: Protective Textiles are textile products and related materials used in the manufacture of protective clothing for personnel working in hazardous environments. Protective clothing includes garments for protection from harmful chemical environment, extreme temperature environments, low visibility, ballistics, and protection from other types of severe impact hazards. Woven fabrics using conventional fibers such as cotton, viscose and polyester are treated with Flame retardant finish for making of FR apparel and upholstery. Working suits for professional groups that are occasionally exposed to unforeseen flames and heat are also made from fiber blends such as Basofil/cotton and Basofil/wool (Anonymous, 2006).

CONCLUSION

Cotton is a versatile fiber with multiple uses ranging from food to cloths. The use of cotton in different sectors can be increased by blending it with other fibers, by using new methods and processes to produce a durable and advanced fiber material such as nonwoven. Apart from traditional uses like clothing, cotton fibers, yarns and fabrics developed with functional properties such as water repellent , moisture management , soil and stain removal that is self-cleaning, antibacterial performance can increase their share in Protech, Sporttech, Hometech, Medech, agrotech, buildtech, mobiltech, as there is an increase observation of health and hygiene, use of protective clothing in everyday consumer clothing as well as increase in automobiles manufacturing in India.With organic consciousness and increasing market demand for natural products, there is a need to exploit the full potential of the "white gold" of India, as the name given to cotton.

REFERENCES

Anonymous, 2006. Indian technical textile market. Retrieved from http://shows.nonwovens-industry.com/articles/2006/09/the-indian-technical-textiles-market

Anonymous, 2009. Home Furnishing Industry Overview, An Introduction. Retrieved from:http://www.teonline.com/home-furnishing/industry-overview.html.

Anonymous, 2013. Buildtech Textiles. Retrieved from http://textilecentre.blogspot.in/search/label/Buildtech%20Textiles

Anonymous, 2014. Invest in cotton-based technical textiles: SIMA chairman. Retrieved from : http://www.technicaltextile.net/news/invest-in-cotton-based-technical-textiles-sima-chairman-167259.html

Anonymous, 2015. Material on technical textiles. Retrieved from: http://texmin.nic.in/sector/note_technical_textiles_ammt.pdf

Anonymous, 2015. Textile industry in India.http://www.ibef.org/industry/textiles.aspx

Ayala, P.N. 2014. 10 Indian organic clothing brands that you should be proud of wearing. Retrieved from http://www.thealternative.in/lifestyle/10-indian-organic-clothing-brands-that-you-should-be-proud-of-wearing/

Cattermole, T. 2010. The future of cotton. Retrieved from http://www.gizmag.com/future-of-cotton/17077/

CBI Market Survey. 2008. Product Characteristics, The household and Furnishing Textile Market in the EU. Retrieved from: www.cbi.eu

Chremours. Teflon™ fabric protector. Retrieved form https://www.chemours.com/Teflon_Fabric_Protector/en_US/products/benefits_teflon_fab.html

Cotton Incorporated. 2010. Cotton incorporated supply chain insights: The shifting Japanese apparel consumer. Retrieved from http://www.cottoninc.com/corporate/market-data/supplychaininsights/the-shifting-japanese-apparel-consumer/japanese-consumer-10-10.pdf

Cotton Incorporated. 2013. Cotton incorporated supply chain insights: Courting the Mexican apparel consumer. Retrieved from http://www.cottoninc.com/corporate/Market-Data/SupplyChainInsights/Courting-Mexican-Apparel-Consumer/

Cotton Incorporated. Storm cotton.Breathable water repellent protection. Retrieved from http://www.cottoninc.com/product/Product-Technology/Water-Repellent/Storm-Cotton/Technology/

Crumbley, R. Cotton incorporated: New Innovations for Cotton Products. Proceedings of the Symposium on Natural Fibers. USA. Retrieved form ftp://ftp.fao.org/docrep/fao/011/i0709e/i0709e12.pdf

Das, S. 2010. Fibers and Fabric Used In Home Textiles. *Performance of Home Textile.*Woodhead Publishing India Pvt. Ltd. New Delhi.

Dubey, R., Shami, T.C., Rao, B.K.U. 2009. Microencapsulation technology and Applications. *Defence Science Journal.*59(1):82-95. Retrieved from: file:///C:/Users/Compaq/Downloads/1489-5768-1-SM.pdf

Foulk, J.A., Reihmane, S.A. and Triprin, M.G.1999. Physio-mechanical properties of composites from recycled polyethylene and linen yarn production wastes. *Mech Compos Mater.* **35** :139-46

Gopalakrishnan, D. Technical Textiles –A vision of Future. Retrieved from http://www.fibre2fashion.com/industry-article/textile-industry-articles/technical-textiles/technical-textiles1.asp

Gupta V, Yadav N, Gupta S. 2014. Shape memory materials: An innovative way to improve properties of cotton. *Pariplex-Ind. Jour. Res.* **3 :** 200-02

ICRA Managemnt Consulting Services. 2010. Sportech-current and future scenario in India. : Theme Paper. FICCI.Retrieved from www.imacs.in/store/corp_adv/Sportech%20-% 20 Current % 20 and %20 Future % 20 Scenario % 20 in % 20 India, % 20FIICI % 20 and % 20 Ministry % 20 of % 20 Textiles % 20 Seminar, %20Dec %20 2010.pdf

Indian Brand Equity Foundation. 2015. Cotton Industry in India. Retrieved from http://www.ibef.org/exports/cotton-industry-india.aspx

International Trade Centre. Types of cotton. Retrieved from http://www.cottonguide.org/cotton-guide/market-segments-types-of-cotton/

Kranthi, K.R. 2014. How colourful is the future of naturally colored cotton? *Cotton Statistics & New: Cotton Association of India.* **1:** 1-4

Rakshit, A.K., Ghosh, S.K. and Talukdar, M.K. 1994. Potentiality of cotton nonwoven fabrics. *Indian Jour. Fiber Textile Res.* **19 :** 224-27

Ramkumar, S. Growth opportunities in Nonwoven and Technical Textiles Industry in India. Retrieved from:http://www.fibre2fashion.com / industry-article/textile-industry-articles/growth-opportunities-in-nonwoven/growth-opportunities-in-nonwoven1.asp

Reddi, L. N. 2003. *Seepage in Soils: Principles and Application.* John Wiley & Sons, Inc. New Jersey.

Muthu, S.S. 2014. Roadmap to Sustainable Textiles and Clothing: Eco-friendly Raw Material. Springer. Singapore.

Shishoo, R.2005. Textiles in sport.Woodhead Publishing Limited, New Delhi.

Shishoo, R.2015. Textiles for sportswear.Woodhead Publishing Limited, New Delhi.

Srivaramakrishnan, C.N.2015. Functional Finishes on Technical Textiles. *Int. Jour. Tech. Engineering Processes.***1 :** 29-32

Tarimala, S., Kothari, N., Abidi, N., Hequet, E., Fralick, J., Dai, L.L.2006. New approach to antibacterial treatment of cotton fabric with silver nanoparticle–doped silica using sol-gel process.*J. Appl. Polym. Sci.* 2006, **101 :** 2938–43

Vasile, S., Grabowska, K.E., Wrobe, I.L.C. and Githaiga, J.2010. Analysis of Hybrid woven fabrics with shape memory alloy wires embedded. *FIBERS & TEXTILE in Eastern Europe.* **18 :** 64-69

Wright, A.M.2003. Cotton: The Fabric, Fiber, Flavor of our lives. Retrieved form http://aces.nmsu.edu/pubs/resourcesmag/spring03/cotton.pdf

Yeh, J.T., Chen, C.L., Huang, K.S.2007. Preparation and application of fluorocarbon polymer/SiO2 hybrid materials, part 2: Water and oil repellent processing for cotton fabrics by sol-gel method. *J. Appl. Polym. Sci.* **103 :** 3019–24.

Zhang, X. 2004. Investigation of Biodegradable Nonwoven composites based on Cotton, Bagasse and other Annual plants. *M.Sc. (Thesis).* B.S. Tianjin University, Tianjin China

Zhong, W. 2012. An Introduction to Healthcare and Medical Textiles.DEStech Publications, Inc

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Cotton production strategy for the next decade by seed industry perspective

VIPIN S. DAGAONKAR
Bayer Crop Science, Hyderabad - 500 082
E-mail : vipin.dagaonkar@bayer.com

Indian cotton has witnessed dynamicchangesright from cultivation of predominantly diploid varieties in the beginning to cultivation of allotetraploid *hirsutum* varieties to hybrids and now the transgenic era. Each phase had its own reasons and merits for adoption. Although this kept India as leading cultivator of cotton and maintained its position in top three cotton producing countries in the world, on producibility front, we were well below the average world productivity for the obvious reasons of holding size, dependence of major cultivable area on monsoon and adoption of semi-mechanized cultivation practices.

About 70 per cent of global cotton production comes from four countries which includes India, China, USA and Pakistan. Present global area of cotton cultivation area is 34.1 M. ha and is expected to remain between 32 to 35 M. hain the coming decade and cotton consumption is going to increase with the growing population.With fluctuating acreages in cotton growing countries, focus will be primarily on India for meeting increasing demand of cotton.

Climate change is likely to bring a noticeable increase in surface air temperature in future, becoming more conspicuous after 2040. It is likely to bring significant changes in the hydrological cycles. As a result major river basins are expected to experience water shortages. Studies have indicated that enhanced CO_2 levels up to 650 ppm and increased temperatures up to 40^0C have been found to be optimum for cotton crop growth but the climate change is also expected to bring changes in disease and pest dynamics in the crop. (Cotton and Climate Change-Impacts and Options to Mitigate and Adapt, International Trade Center, 2011). These changes are also going to influence competing weeds and will need proper approaches to control them.

India has seen a dramatic change in the productivity levels after introduction of transgenic technology for insect resistance. Productivity of cotton lint close to 322 kg/ ha (2002-2003) has increased to 537 (2014-2015) kg/ha (Annual Report AICCIP) after adoption of the *Bt* technology and has been evenat that level for some time. In India, cotton procurement prices are based on seed cotton. This is unlike other countries where the prices are based on the lint.Ginning turnout is getting a secondary focus as a trait of improvement. The level of heterosis in cotton isnot comparable with crops such as Corn and hence the expected yield gains are not somehow reflected in the production gains of the country.

Cotton continues to face a stiff challenge from man-made fibers in the growing consumer demand. Manmade fibers will grow at an increasing rate than cotton in the coming decade but Indian market is expected to be more cotton centric.In spite of the growing consumer demand, cotton will be losing the pace of growth to man-made fibers on account of several factors such as procurement prices, reduction in arable land, stiff challenge from food crops for arable land and challenges of cultivation. There is also a need to bring more discipline in cultivation of the crop to ensure better quality cotton in order to maintain the competitiveness of the crop with the man-made fibers.Breeders also need to focus on the requirements of the cotton based industry mainly the apparel industry to identify their needs and breed cotton to meet their expectations.

Hybrid cotton era has really helped the Indian seed industry to reach its current position in the business. Although the seventies and eighties belonged to the public sector in delivering high yielding cotton hybrids in the market, Indian seed industry has contributed to its success by taking on the onus of seed production and distribution in the market. Success stories of H 4, H 6 and NHH 44 are a testimony of this phenomenon. This has also stimulatedseed industry to set up own breeding programs in the country and the result is that the business has become more competitive. Seed industry also owns the credit of popularizing the cotton seed production technologies in the country. Today nearly 10 per cent (estimated) of the cotton seed production is done using genetic male sterility.It has also an important role in introducing and popularizing transgenic technology for insect resistance in the country.

Indian seed industry produces approximately 27,000 M tons of processed hybrid seed every year to meet the market demand. With changes in the agronomy, the seed rates are expected to grow beyond 2 packets (0.450 kg packing) from current 1.65 packets/ac. This increasing demand of the seed in the coming decade have to be met with ever increasing challenges from climate, increasing cost of inputs and labour, somewhat stationary production areas and price cap on the end product. Technology evolution is reducing the breeding cycles and the increasing challenge to the crop is making the breeding processes very complex.

The main challenges foreseen by the industry in cotton cultivation are-

1. Ensuring cotton acreages for seed production in future
2. Seed production, both quality, quantity and value
3. Emerging pest and disease scenario
4. Dawdling technology evolution process

Way out

1. After evolution of *Bt* cotton in the country and good market sentiments, the area under the crop increased by around 30-35 per cent when compared to the non-GM cotton era in the country. This has resulted in spread and cultivation of the crop under marginal soil conditions and low management. Theseconditions adversely affect the production, productivity and quality of the produce. There is a need to identifyand promote alternative cropsthat require lower inputs compared to cotton and let cotton crop be limited to core cultivationand better management areas.
2. Improved agronomies. Agronomic techniques for higher plant population per acre need to be optimized. This will improve the per sq. unit production thereby increasing production in the country. Standardization of the dosages of plant growth regulators and harvest aid

chemicals for use on cotton needs to be done while promoting the concept of high density planting in cotton.

3. More importance should be given to lint recovery in the breeding programs. We need to shift our approach from per acre seed cotton yield to per acre lint yield. This will have a direct impact on the production and productivity of cotton crop in the country. Higher lint recovery in cotton needs to be incentivized in procurement as a step to improve productivity of the country.
4. Strengthen efforts in molecular breeding for native trait discovery for the existing and emerging pest and disease scenario in the country. This will support the crop by way of stabilizing the production. Molecular breeding techniques can also be used to study diversity within the germplasm and improve germplasm resources in the country for yield and quality enhancement.
5. Improving the seed production efficiency in the crop by promoting use of male sterility system.
6. Focus on plant architecture in breeding to meet the future needs of high density crop cultivation.
7. Streamlining GM regulatory system to encourage competition in established traits (IR and HT) and open door for additional biotic and abiotic events.
8. Relax restrictions on germplasm flow. There is lot more germplasm outside India,therefore India would gain more than it loses in exchange. Current “Indianization” of imported germplasm discourages industry from sending new elite material that will not be considered proprietary.
9. Strong post harvest processing facilities need to be developed in light of the mechanized picking operations expected to be adopted in future.
10. Consortium based approach to address major challenges in the crop with equal public private partnership.
11. Breeding approaches to develop specialty fibers to meet the textile industry requirements.
12. Create an environment that allows seed industry to be more market driven to encourage more investment and competition.

A consorted effort with above considerations will certainly help us making bright future for the crop for overall benefit of the farming community and the country.

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Bio-intensive pest management in cotton: Do's and Don'ts of whitefly management

S. KRANTHI*, K. R. KRANTHI, RISHI KUMAR, D. MONGA, V. S.NAGRARE AND PRABHULINGA TENGURI

Central Institute for Cotton Research, Nagpur

E-mail : sandhya.kranthi@gmail.com

Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae) is one of the most damaging pests worldwide on cotton. In Indian cotton, it has caused serious damage especially since the introduction of *G. hirsutum*. It also affects several crops including horticultural crops and is polyphagous in nature. It is a pest that often turns into epidemics as a consequence of insecticide misuse. Its nymphal and pupal stages are sessile and are often found on the abaxial side of the leaf in cotton and are difficult to access with contact insecticides. They suck sap from the phloem and damage by *B. tabaci* reduces lint yield while also causing stickiness as a result of honey dew and staining of lint as a result of dark sooty mould development. It is a pest that has evolved into biotypes of which the B biotype is more serious. Adult whiteflies transmit the leaf curl virus, A large number of parasitoids, predators and fungi are reported on whitefly and are known to exert natural control in the field. This balance is often affected by indiscriminate use of broad spectrum insecticides especially in cotton. General predators and Aphelinid parasitoids act as key factors in the population dynamics of this pest not only in cotton but in several crops. In India, *Encarsia sps* and *Eretmocerus mundus* have been reported as the dominant parasitoids of the cotton whitefly. In the absence of natural enemies pests such as *B. tabaci* increase in numbers very rapidly and may even aggravate the problem as reported from Sudan & USA.

A whitefly epidemic was witnessed in North India this year. Farmers have suffered losses due to damage caused to cotton crop by the whitefly in North zone (Haryana, Punjab and Rajasthan). During 2015, high incidence of whitefly was observed from the month of July onwards. The population of whitefly was observed above (economic threshold level) ETL during the entire season throughout the zone up to October, 2015.

Reasons for the outbreak are enumerated as follows:

Crop factors:

a) Multiplicity of Bt hybrids usually of bushy nature.

b) Cultivation of Bt hybrids that were tested and reported as unsuitable by virtue of susceptibility to leafcurl and whitefly.

Production factors

c) Late sowing of cotton in some belts (such as Punjab) where incidence and damage was higher than in those areas where sowing was on time.

d) Use of fertilizers over and above the recommended dose.

e) Imbalanced use of selected fertilizers like urea.

f) Intense weed management on bunds and uncultivated areas during the season.

g) Use of unapproved and/or spurious phytohormones.

h) Exposure of crop to frequent water stress.

Insecticide factors:

i) Use of broad spectrum insecticides over top early in the season

j) Using unapproved tank mixtures of insecticides and cocktail of chemistries, including 'phytohormones".

k) Use of chemistries that promote greening or cause a shift to vegetative stage.

l) Complete absence of the use of soft chemistries like neem products.

m) Use of repeated sprays of groups of insecticides with similar mode of action.

n) Use of higher doses of pesticides.

o) Inability of sprayed products to reach the target sites.

p) Mis-mangement of insecticide use not only on cotton but on other crops in the ecosystem.

Climatic factors:

q) Prolonged hot dry spells

r) Poor distribution of rainfall.

s) High day temperatures.

Dos and don'ts for whitefly management: Cotton farmers resort to indiscriminate sprays of insecticides including tank mixes. Such insecticides are also sprayed repeatedly in the cotton season, not only on cotton but on other crops in the ecosystem such as paddy in North India. About 35 insecticides are registered for use in India against the cotton whitefly. Some of the registered insecticides, like Triazophos, Monocrotophos belong to the group I WHO category (ie highly hazardous and carries a red label) and Group II like Ethion, Chlorpyriphos, Fipronil (moderately hazardous and yellow label). These insecticides are comparatively cheaper than those belonging to the Group III or Group U. In light of this, farmers overuse Ethion, Triazophos, Monocrotophos often as tank mixes resulting in a decimation of natural enemies in the sprayed ecosystem.

1. **Strictly avoid synthetic pyrethroids, acephate or insecticide mixtures :** These are broad spectrum insecticides. They are also low priced as compared to new molecules. Repeated use of synthetic pyrethroids has documented resurgence of the whiteflies as in 1997-98 in Guntur in Andhra Pradesh where pyrethroid use for management of *H. armigera* resulted in a serious outbreak of whitefly. Acephate is a broad spectrum organophosphate that produces a primary metabolite, methamidophos. Acephate is harmful to predatory mites, lace wings, ladybirds, *Trichogramma* and moderately harmful to rove beetles while being toxic to bees and earthworms. Acephate belongs to Class II of WHO rating –ie moderately hazardous. Its metabolite methamidaphos is harmful to predatory mites, Spiders, Flower bugs *Anthocoris sps*, lady birds, ground beetles and *Trichogramma* while being harmless to flower bugs belonging to the *Orius sps*. Methamidophos is moderately harmful to rove beetles while being toxic to bees, earthworms and fish at a specified dose. It is categorized as a Class 1b compound- ie is highly hazardous with oral and dermal LC50 of 5-50 and 50-500 mg/Kg body weight to rats. Cypermethrin at 100g/L is harmful to predatory mites, spiders, flowerbugs, hoverflies, rove beetles, ground beetles, *Trichogramma* and fish but moderately harmful to lacewings and harmless to ladybirds. Cypermethrin belongs to WHO rating of Class II. Tank mixtures of insecticides are undesirable as it gives the freedom to mix more than two molecules together with dangerous consequences. Poisoning by unauthorized tank mixing cannot be remedied readily by known antidotes. Tank mixtures used in North India this year may have led to an imbalance in the natural enemy fauna, enhanced fecundity of

whiteflies through hormoligosis. Together with environmental and ecological factors, misguided use of insecticides has added to the whitefly outbreak in cotton in India.

2. Avoid excessive urea : Excessive nitrogen promotes leaf succulence and predisposes the plant to attack by sucking pests. Urea when applied, promotes greening and causes the plant to put forth new foliage thus making it vulnerable to pest attack. Urea also pushes the plant toward the vegetative stage causing a change in the microclimate that may be favorable to whiteflies. It must be mentioned that certain additives to insecticide formulations like cis jasmone (http://www.google.com/patents/EP2549878A2?cl=en) have been patented by insecticide companies (eg Syngenta) that promote among others, greenness in crops. Enhanced greenness may make the plant vulnerable to pest attack. Excessive urea also impacts the uptake of potassium and phosphorous, resulting in nutrient imbalance. Farmers often also use excessive urea in cotton as it is sold under subsidy.

3. Use yellow sticky traps : Whiteflies are reported to be attracted to yellow color. The adult whiteflies are flying insects. Sticky traps were used as a monitoring tool rather than for management. Sticky traps also need to be changed at regular intervals and are vulnerable to loss of stickiness due to abiotic factors like rain, heat etc Historically these traps have been used as stationary units. Whitefly adults are disturbed by human and animal movement in the field and this was exploited in using the yellow sticky trap as a mobile monitoring unit. Experiments were conducted to standardize the use of yellow sticky as mobile units where they were stuck to the wheels of the plough and even to the trousers of the operator on the outer thigh so as to trap flying insects (Kranthi et.al. unpublished). The latter was effective in whitefly management and can be used early in the season as a mechanical measure to reduce populations when intercultural operations are carried out in the field. The use of sticky traps as mobile monitoring units in the field must be timed so as to prevent the trapping of natural enemies. A recent gadget, in patent process, CICR adult whitefly suction trap, is aimed at minimizing adult whitefly population in the field early in the season when populations of adult whiteflies is more. The feasibility in reducing insecticide sprays and its economics is being worked out.

4. Spray 5 per cent emulsion of neem oil, castor oil, fish oil rosin soap or 1% Soap. : Whitefly adults are delicate and flying in nature. These characters enable control with water and oil sprays that are eco-friendly and effective options if used early in the season prior to the use of deleterious broad spectrum insecticides. Azadirachtin, the major terpenoid of neem, has been found harmless to a large group of natural enemies. It is harmful to select predatory mites and flower bugs and moderately harmful to parasitoids of the *Aphidius* sps. Oils are also known to form a thin film over the insect, especially whitefly nymphs that are immobile and block their spiracles thus affecting respiration.

Soaps, detergents and oils also remove insect cuticle wax, have a physical action, of repellency or cell membrane disruption. Household cooking oils with dish washing detergents as emulsifiers have been shown to be effective for home garden use. Castor oil and neem seed oil, two non-edible but abundant oils can be very useful in agricultural programs. The use of less expensive petroleum oils for insect control, especially in orchard crops is a recent development for insect control. However in some reported experiments with the use of detergents, adults were observed freeing themselves and flying away from the surface of rapidly drying paper plates sprayed with 0.5% detergent without any apparent adverse effect. These results indicate that complete coverage of the leaf undersurface is required, with adequate spray fluid deposition to entrap adults and to kill the nymphs. A high quantum of spray requirement could limit the practicability and use of these materials. On the other hand, applications timed to coincide with humid conditions could reduce evaporation rate and thereby increase the efficacy of detergents. Phytotoxicity, however, of these products must be ruled out before use.

5. Insecticides for whitefly management: Whiteflies on cotton can be managed with the sensible use of novel and new chemistries with minimum damage to the ecosystem. Insecticides effective against whiteflies categorized as new and novel belong to those interfering with metamorphosis, those inhibiting metabolic processes, those inhibiting cuticle biosynthesis and those blocking feeding. Molecules acting on the nervous system can further be characterized as group 1, group 2, group 3 and group 4 that include chemistries acting as Acetylcholinesterase inhibitors, GABA gated chloride channel antagonists, Sodium channel modulators and Acetylcholine receptor agonists, respectively. Diafenthiuron, Buprofezin, Pyroproxyfen, Spiromesfin and Emamectin benzoate are some of the popular new chemistries that may be sprayed. Classes to which insecticides for whitefly control belong fall under 10 groups. They are group 1A, 1B, 2A, 3, 4A, 7C, 9B, 12A, 16 and 23 details of which are available on the IRAC website.

In order to conserve susceptibility to insecticides, effective IRM strategies involve alternations or sequences of chemistries have different modes of action. This ensures that insecticides of the same group are not repeatedly used. A window strategy is also recommended based on the stage of the crop and biology of the pest. CICR advisories available on its website may serve as a beginning. *B.tabaci* has more than 39 compounds against which resistance has been reported

a) Diafenthiuron: Diafenthiuron is a pro-insecticide, which has first to be converted to its active form which in turn acts on portions of the energy-producing enzymes in the mitochondria. This results in immediate paralysis of the pest after intake or contact with the product thus implicating a quick knock down effect (http://www.syngenta.com/global/corporate/en/products-and-innovation/product-brands/crop-protection/insecticides/Pages/polo.aspx). Potency of diafenthiuron against various stages was in the order larvae > adults > pupae > eggs. Diafenthiuron affects both nymphs and adults resulting in more flexible application timing and longer lasting control. It belongs to a unique chemical group allowing control of insects and mites resistant to major chemical classes such as OPs or pyrethroids. It has a broad spectrum of activity, being an insecticide as well as an acaricide, allowing simultaneous control of sucking insects and mites. It has translaminar action and controls hidden pests in the plant canopy and on the underside of the leaves. It degrades into an urea derivative resulting in a phytotonic effect as claimed by the company. Diafenthiuron 250 SC at 500g ai/Ha is harmless to predatory mites and coccinellids and is moderately harmful to lacewings and *Aphidius* species but is harmful to *Phytoseius* sp, flower bugs and *Trichogramma.* It shows toxicity bees and fish (IOBC rating 2009).

b) Buprofezin : Non neurotoxic insect growth regulators are used for whitefly management in Israel and the US. Buprofezin was the first selective IGR introduced for control of *B. tabaci* in cotton. It is a thiadizine chitin synthesis inhibitor selective in homopterans. It targets the immature stages. It also causes nymphal mortality through inhalation by nymphs and also by direct absorption through the integument. It does not have systemic activity through soil or translaminar action on foliage. In order to prevent resistance development Buprofezin is recommended for use only once in a season in the USA. Although the degree of effects by buprofezin with instar, buprofezin at the higher concentrations (500 and 1,000 mg ai/liter) reduced survival rates 17-47% and prolonged the overall development from first instars to adult emergence by 2 or 3 d when first instars were treated. The first instar is the most vulnerable stage and Buprofezin should probably be used as the first insecticide molecule when pest populations are homogenous. Buprofezin at three tested concentrations (100, 500, and 1,000 mg ai/liter) did not affect the viability and development of eggs, third instars and pupae of *Chrysoperla.* Buprofezin caused mortality in early larval stages of *Encarsia luteola* Howard, *E. eremicus* and *E. tejanus* Rose and Zolnerowich. However, buprofezin was benign to adults of several species of *Eretmocerus* and *Encarsia*. In North India, buprofezin runs the risk of being over used during the season as it is an insecticide for hopper control in rice and on whiteflies in cotton. Both pyriproxyfen and buprofezin prevent honey dew sugars and sooty mould contamination in cotton. On the downside, these molecules are not toxic to adults and thereby are not very useful in suppressing CLCuD in cotton.

c) Pyriproxyfen : Pyriproxyfen on the other hand is a non neurotoxic, non terpenoidal juvenile hormone analogue and disrupts normal hormonal activity. It is effective in suppressing embryogenesis, metamorphosis and adult formation. It however is not toxic directly to adults. It has translaminar activity, ovicidal effect by suppressing embryogenesis by direct contact and has an indirect action through transovarial action through adult contact. Timing of its spray application is therefore crucial.

d) Spiromesifen : Spiromesifen belongs to Group 23 and is an inhibitor of lipid biosynthesis. It is a new insecticide derived from tetronic acid. Adult *B. tabaci* mortality rate after spiromesifen treatment (5 mg L”1) was 40%. Treatment with 0.5 mg /L reduced fecundity per female by more than 80%, and fertility was almost nil. LC50 for eggs was 2.6 mg/L, and for first instar 0.5 mg/L. Scanning electron microscopy revealed that eggs laid by treated adult females had an abnormally perforated chorion, and females were unable to complete oviposition. Light and fluorescent microscopy showed significantly smaller eggs following treatment, and smaller, abnormally formed and improperly localized bacteriomes in eggs and nymphs. Spiromesifen showed no cross-resistance with other commonly used insecticides from different chemical groups, and resistance monitoring in Israel showed no development of field resistance to this insecticide after 1 year of use. The strong effect on juvenile stages of *B. tabaci* with a unique mode of action and the absence of cross-resistance with major commonly used insecticides from different chemical groups suggest the use of spiromesifen in pest and resistance management programmes. Baseline toxicity of spiromesifen was established for laboratory susceptible and field collected *B tabaci* biotype B, populations in Florida in 2005 and 2006, respectively, using a leaf dip bioassay method for 2nd instar. LC_{50} values for field populations of *B. tabaci* ranged from 0.63 mg ai / L to 0.86 mg ai/L in 2005 and from 0.46 mg ai/L to 2.08 mg ai /L in 2006. No population had a RR_{50} value over 3.5 in either year and the fiducial limits of the LC_{50} values for the laboratory and field populations overlapped, indicating no differences among them. The predominant mode of intoxication of whiteflies is by both contact and direct feeding. Nymphal stages of whiteflies are affected more rapidly than the adults and the nymphs treated with spiromesifen did not molt properly and failed to reach adulthood. To date active ingredient has not been reported to show cross resistance with any insecticide for which resistant mite or whitefly field populations have been identified .

IGRs are selective, effective and have immense potential in conservation biological control. On seasonal basis population densities of 20 arthropod predators declined just 7% on average over a 3 years period when either IGR was used compared with an average reduction of 32% when broad spectrum insecticides were used. A single application of either IGR was sufficient to control *B tabaci* populations throughout much of the growing season while as many as 5 applications of broad spectrum compounds were needed to achieve similar levels of season – long control.

Steps to prevent the buildup of white flies:

1. Use of host plant resistant varieties or hybrids: *Gossypium arboreum* or Desi cotton is tolerant to whiteflies due to their structural anatomy, physiology and biochemical processes. In the 1970s *G. arboreum* was widely cultivated in North India and whiteflies were less of a problem until the introduction and misuse of pyrethroids. This species is also immune to the cotton leaf curl virus. On a practical front farmers are reluctant to grown *G. arboreum* cotton as they fetch lower market prices and do not yield as much as Bt cotton if grown conventionally.

Policy changes that may help: What the Government can do

a) By stepping up the minimum support price of *G. arboreum* at least to be on par with *G. hirsutum*
b) Incentives to farmers growing *G. arboreum* by way of supply of good quality seed.
c) Setting up and strengthening of value addition facilities such as surgical cotton units.

Technical support: What scientists can do

a) Promote long linted spinnable varieties as well as those varieties that are amenable to surgical purpose.
b) Ensure timely availability of seeds of short duration compact non shedding genotypes of *G. arboreum* and its timely sowing.
c) Promote its cultivation in High Density Planting system. This is a concept being promoted by CICR where a plant population of 1, 40,000- 1.60,000 plants are maintained per acre and varieties but not hybrids are amenable to this

system of cultivation.

d) Promotion of HDPS concept means ensuring the availability of large quantities of seed as the recommended seed rate is 5kg per acre.

2. Whiteflies are insecticide induced. The best way to manage whiteflies is to delay the use of insecticides on cotton. Insecticides are non selective exerting toxic effects both on the pest and their natural enemies.

a) Timely sowing that is often dependant on canal water release should be strongly advocated as early sown crop is more tolerant to whiteflies.

b) Selection of tolerant genotypes as discussed in point 1 can effectively delay the use of insecticides.

c) Promote the use of authentic neem formulations during the early part of the season.

d) Set up demonstration plots in each district comparing misuse of insecticides to rational insecticide use.

Policy changes that may help:

a) In fact if the first point is acted upon by the Government this point may become redundant.

b) Deter dealers from stocking up and selling insecticides that promote whitefly flare up in cotton such a pyrethroids or combinations containing it, Fipronil , acephate etc.

c) Subsidise authentic neem formulations.

d) Do not offer subsidy on insecticides.

e) Subsidise sticky traps round the year so as to promote its use.

Technical support:

a) Do not recommend the use of insecticides that are known to cause a flare up of whiteflies.

b) Do not promote the use of Monocrotophos or other plant greening chemicals on cotton.

c) Restrict fertiliser use to the recommended dose. In fact preliminary research at CICR has revealed that avoidance of chemical fertilizer application in the first 45 days may limit the outbreak of sucking pests. However this strategy needs further experimentation before it can be recommended to farmers.

d) Clean cultivation is an important step towards keeping fields whitefly free. It is suggested that fields including bunds are maintained weed free before the onset of season rather than doing so during the season.

e) Promotion of the use of CICR adult whitefly suction trap when infestation levels are low on cotton during early part of the season and the use of the suction trap on identified alternate hosts of the whitefly. In addition promotion of the use of sticky traps in large numbers throughout the year to limit whitefly numbers in a given field.

f) List out insecticides that are permitted for use on cotton in India.

g) Identify their rating based on WHO (World Health Organization) as well as by IOBC (International Organization for Biological Control).

h) Promote the concept of conservation biological control. The goal of conservation biological control is to modify the environment such that the advance and associated activity of biological control agents are enhanced, leading to improved pest management. Biological control in this case , when insecticides also play an important role in pest suppression will depend on the use of more selective materials and for more bio-rational approaches to minimize their effects on natural enemies.

i) Recommend the use of plain soap water when populations are just about to build up. Before recommending it one should ensure that the farmer has not sprayed any insecticide on his crop.

j) Despite this, if population begins building rapidly use of insect growth regulators is recommended. World over 2 non neurotoxic IGRs are popular for whitefly management – Buprofezin and Pyriproxyfen.

To summarize integrated pest management for whiteflies is crucial to prevent epidemics. Farmer, extension worker, state agricultural departments and scientists working not only in cotton but in other crops of the ecosystem need to be sensitized on intelligent insecticide use.

Suggested further reading:

Mohd Rasdi, Z., Che Salmah, M. R., Abu Hassan, A., Hamady. D., Hamaseh A. Fauziah Ismail, 2012. Field Evaluation of Some Insecticides on Whitefly (*Trialeurodes vaporariorum*) and Predator (*Macrolophus caliginosus*) on Brinjal and Tomato Plants. *Asian Jour Agri Rural Dev,* p.2 : 302-311 ISSN (P): 2304-1455, ISSN (E): 2224-4433 Volume 2 No. 3.

J.C. Palumbo, A.R. Horowitz, N. Prabhaker 2001. Insecticidal control and resistance management for *Bemisia tabaci,* Elsevier Science Ltd, PII: S 0 2 6 1 - 2 1 9 4 (0 1) 0 0 1 1 7 – X, *Crop Prot* **20** : 739–65.

Steven E. Naranjo , Peter C. Ellsworth 2001. Challenges and opportunities for pest management of *Bemisia tabaci* in the new century, Elsevier Science Ltd. PII: S 0261-2194(01)00107-7. *Crop Prot* **20** : 707.

Walker A. Jones, M. A. Ciomperlik and D. A. Wolfenbarger 1989. Lethal and Sublethal Effects of Insecticides on Two Parasitoids Attacking *Bemisia argentifolii* (Homoptera: Aleyrodidae) *Biological Control* **11** : 70–76, Article no. BC970581.

Zidan, Lobna. T.M, M.H. Rashwan,M.A.A Abd-El-Razik 2013. Comparative Curative and Preventive Ovicidal Effectiveness of Certain Selected IGRs and Insecticides Against The Cotton Leafworm and Sweetpotato White Fly, *New York Sci Jour* **6**.

Rafael Caballero , Sabrina Cyman and David Schuster 2013. Baseline Susceptibility of *Bemisia tabaci*, Biotype B (Hemiptera: Aleyrodidae) to Chlorantraniliprole in Southern Florida, *Florida Entomologist* **96**.

S. Ahmed, M. S. Nisar, M. M. Shakir, M. Imran ,K. Iqbal 2014. Comparative efficacy of some neonicotinoids and traditional insecticides on sucking insect pests and their natural enemies on bt-121 cotton crop, *Jour of Ani Pla Sci,* **24** : 660-63 ISSN: 1018-7081.

Wen Xie, Yang Liu, Shaoli Wang, Qingjun Wu, Huipeng Pan, Xin Yang, Litao Guo, and Youjun Zhang 2014. Sensitivity of *Bemisia Tabaci* (Hemiptera: Aleyrodidae) to Several New Insecticides in China: Effects of Insecticide Type and Whitefly Species, Strain, and Stage, *Jour Ins Sci* **14** : 261 DOI: 10.1093/jisesa/ieu123.

S.X. Ren, S. Ali, Z. Huang and J.H. Wu 2010. *Lecanicillium muscarium* as microbial insecticide against whitefly and its interaction with other natural enemies, Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology A.Mendez-vilas(Ed.)

M. Kannan, S. Uthamasamy, S. Mohan 2004. Impact of insecticides on sucking pests and natural enemy complex of transgenic cotton, Curr Sci, **86** : 5.

Rattan R .S, Purohit H, Patel C, Suvagia P, Singh V, Portillo H, I. Billy Annan, Juan M. Alvarez 2015. Effect of Cyantraniliprole on Feeding Cessation of Q Biotype Bemisia tabaci (Gennadius) (Hemiptera: Aleyrodidae), *Adv Entomology,* **3** : 56-64.

M. Naveed, A. Salam, M.A. Saleem Ali H. Sayye 2008. Effect of Foliar Applications of Some Insecticides on Bemisia tabaci, Predators and Parasitoids: Implications in Its Management in Pakistan, *Phytoparasitica* **36** : 4.

N. Aggarwal, D. S. Brar 2006. Effect of different neem preparations in comparison to synthetic insecticides on the whitefly parasitoid *Encarsia sophia* (Hymenoptera: Aphelinidae) and the predator *Chrysoperla carnea* (Neuroptera: Chrysopidae) on cotton under laboratory conditions, *J Pest Sci* **79** : 201–07.

Steven E. Naranjo, James R. Hagler, Peter C. Ellsworth 2015. Whitefly Management in Arizona: Conservation of Natural Enemies Relative to Insecticide Regime, Conservation of Natural Enemies Relative to Use of Insect Growth Regulators for Control of Sweet potato Whitefly.

R. Kumar and S. Kranthi and M. Nitharwal and S. L. Jat, D. Monga 2012. Influence of pesticides and application methods on pest and predatory arthropods associated with cotton, *Phytoparasitica* DOI 10.1007/s12600-012-0241-5.

Wen Xie, Yang Liu, Shaoli Wang, Qingjun Wu, Huipeng Pan, Xin Yang, Litao Guo, Youjun Zhang 2014. Sensitivity of Bemisia tabaci (Hemiptera: Aleyrodidae) to Several New Insecticides in China: Effects of Insecticide Type and Whitefly Species, Strain, and Stage, Entomological Society of America *Jour Ins Sci,* **14** :1-7; DOI: 10.1093/jisesa/ieu123.

J.E. Gonzalez-Zamora, D. Leira, M.J. Bellido, C.Avilla 2004. Evaluation of the effect of different insecticides on the survival and capacity of *Eretmocerus mundus* Mercet to control *Bemisia tabaci* (Gennadius) populations, Elsevier Ltd. doi: 10.1016/j. *Crop Prot* **23** : 611–18.

Pei Liang., Yajie Guo, Xuguo Zhou, Xiwu Gao 2014. Expression Profiling in *Bemisia tabaci* under Insecticide Treatment: Indicating the Necessity for Custom Reference Gene Selection, *PLoS ONE* **9**(1) : e87514. doi:10.1371/journal.pone.0087514.

Mushtaq Ahmad, M. Iqbal Arif , Muhammad Naveed 2010. Dynamics of resistance to organophosphate and carbamate insecticides in the cotton whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) from Pakistan, *J Pest Sci.* **83**:409–20 DOI 10.1007/s10340-010-0311-8.

Kumar.P. H.M. Poehling 2007. Effects of Azadirachtin, Abamectin, and Spinosad on Sweetpotato Whitefly (Homoptera: Aleyrodidae) on Tomato Plants Under Laboratory and Greenhouse Conditions in the Humid Tropics, *Jour Eco Ent* **100**: 411-20.

Gerben J. Messelink, Roos van Maanen, Sebastiaan F. van Steenpaal a, Arne Janssen 2008. Biological control of thrips and whiteflies by a shared predator: Two pests are better than one, Biological Control **44** : 372–79.

J.C. Palumboa, A.R. Horowitz , N. Prabhaker 2001. Insecticidal control and resistance management for *Bemisia tabaci,* Elsevier Science Ltd. PII: S 0261-2194(01)00117-X.

Steven E. Naranjo a, Peter C. Ellsworth 2009. The contribution of conservation biological control to integrated control of *Bemisia tabaci* in cotton, *Biol Cont* **51** : 458–70.

Marcos Fariaa, Stephen P. Wraight 2001. Biological control of *Bemisia tabaci* with fungi, *Crop Prot* **20** : 767–78.

Dan Gerlinga, Oscar Alomar *et.al.,* 2001, Biological control of *Bemisia tabaci* using predators and parasitoids, *Crop Prot* **20** : 779–799Elsevier Science Ltd .PII: S 0261-2194(01)00111-9.

Steven E. Naranjo 2001. Conservation and evaluation of natural enemies in IPM systems for *Bemisia tabaci, Crop Prot* **20** : 835–52. Elsevier Science Ltd. PII: S 0261-2194(01)00115-6.

Huai Yin Wanga , Yang Yanga , Jian Ya Sua , Jin Liang Shena, Cong Fen Gaoa , Yu Cheng Zhub 2008. Assessment of the impact of insecticides on *Anagrus nilaparvatae* (Pang et Wang) (Hymenoptera: Mymanidae), an egg parasitoid of the rice planthopper, *Nilaparvata lugens* (Hemiptera: Delphacidae), *Crop Prot* **27** : 514–22. Elsevier Ltd. doi:10.1016/j.cropro.2007.08.004.

Steven E. Naranjo, Peter. Ellsworth, and James R. Haglera 2004. Conservation of natural enemies in cotton: role of insect growth regulators in management of *Bemisia tabaci, Biol Cont* **30** : 52–72. Elsevier ltd. doi:10.1016/j.biocontrol.2003.09.010.

Gerben J. Messelink , Roos van Maanen , Sebastiaan E.F. van Steenpaal, Arne Janssen 2008. Biological control of thrips and whiteflies by a shared predator: Two pests are better than one, *Biol Cont* **44** : 372–79. Elsevier Inc. doi:10.1016/j.biocontrol.2007.10.017.

M. Bardin , J. Fargues, P.C. Nicot 2008. Compatibility between biopesticides used to control grey mould, powdery mildew and whitefly on tomato, *Biol Cont* **46** : 476–83, Elsevier Inc.. doi:10.1016/j.biocontrol.2008.05.012.

Prabhat Kumar, H.M. Poehling 2007. Effects of Azadirachtin, Abamectin, and Spinosad on Sweetpotato Whitefly (Homoptera: Aleyrodidae) on Tomato Plants Under Laboratory and Greenhouse Conditions in the Humid Tropics, *Jour Econ Ent* **100** : 411-20 .

E. Abou-fakhr Hammadh. J. Mcauslane 2006. Effect of *Melia azadarach* L. Extract on *Bemisia argentifolii* (Hemiptera: Aleyrodidae) and its biocontrol agent *Eretmocerus rui* (Hymenoptera: Aphelinidae), Environ Ent **35** : 740-45 **.**

Bao-Li Qiu, Nasser S. Mandour, Cai-Xia Xu a & Shun-Xiang Ren 2008. Evaluation of the entomopathogenic nematode *Steinernema feltiae* as a biological control agent of the whitefly, *Bemisia tabaci, Interna Jour Pest Manage* **54** : 247–53.

Moshe Inbar, Dan Gerling 2007. Plant-Mediated Interactions Between Whiteflies, Herbivores, and Natural Enemies, *Annu. Rev. Entomol.* **53** : 431–48, s doi:10.1146/annurev.ento.53.032107.122456

Pasco B. Avery Æ Jane Faull Æ Monique S. J. Simmonds 2008. Effects of *Paecilomyces fumosoroseus* and *Encarsia formosa* on the control of the greenhouse whitefly: preliminary assessment of a compatibility study, *Bio Cont* **53** : 303–16 DOI 10.1007/ s10526-007-9073-5.

Gerben J. Messelink, Roos Van Maanen, Renata Van Holstein-Saj, Maurice W. Sabelis, Arne Janssen 2010. Pest species diversity enhances control of spider mites and whiteflies by a generalist phytoseiid predator, *Bio Cont* **55** : 387–98 DOI 10.1007/ s10526-009-9258-1.

Yuxian He Jianwei Zhao, Yu Zheng, Qiyong Weng, Antonio Biondi, Nicolas Desneux, Kongming Wu 2013. Assessment of Potential Sublethal Effects of Various Insecticides on Key Biological Traits of The Tobacco Whitefly, *Bemisia tabaci*, *Internat Jour Biol Sci;* **9** : 246-55. doi: 10.7150/ijbs.5762

6

Functional finishing of cotton textiles

A. SARADA DEVI AND DEEPALI JOSHI

Acharya N. N. Ranga Agricultural University, Hyderabad - 500 030

E-mail : sharadadevi_2000@yahoo.com

Cotton is one of the wonderful fibres gifted to human kind especially in the tropical countries of the world. Cotton textiles are comfortable to wear, possess good absorbency, heat conductivity, tensile strength, abrasion resistance, absence of static problems etc. It is a versatile fibre that can be molded to suit various implied functions. Cotton and other natural cellulosic fibres are chemically reactive unlike most synthetic fibres which are not very reactive and some are considered inert. The reactive groups on the cotton molecule permit permanent attachment of these functional compounds. The surface of the fibre is polar and hydrophilic, which makes the fabric comfortable during wear and useful for absorbent applications such as towels. Furthermore, the fibre has a large surface area and is porous somewhat like a sponge. Other properties of this fibre, which make these modifications possible, are the optimum degree of crystallinity and a useful range of fibre micronaire (denier) and fiber length.

With the advent of science and technology, a new area has been developed in the realm of textile finishing either improving the process or helping to achieve new functional properties which are not possible with conventional finishing. The nanotechnology, plasma enhanced chemical vapour deposition (PECVD) and Layer by Layer (LbL) assembly, use of Phase Change Materials (PCM) are some of the new techniques that have resulted in revolutionary changes in the area of textile finishing. Thus, it is possible today to alter cotton fabric and make it thermal regulatory, self-cleaning, antimicrobial, UV protective and so on.

The nanotechnology which deals with the materials at nano stage has tremendous applications in textile field especially in finishing. Application of nano finishing chemicals provide effective ultra-thin finished surface that enable the textile to exhibit functional property without altering its hand and feel. Nano finishes such as stain resistance, antimicrobial, controlled hydrophilicity / hydrophobicity, antistatic, UV protective, wrinkle resistant and shrink proof abilities can be exploited using this technique for a range of technical textile applications such protective clothing, medical textiles, sportswear, automotive textiles etc.

They are generally emulsified into either nanomicelles, made into nanosols or wrapped in nanocapsules that can adhere to textile substrates easily and more uniformly. Since 275 nanoparticles have a large surface area to volume ratio and high surface energy, they have better affinity for fabrics. Therefore these finishes are more durable, effective and do not adversely affect the original handle and breathability of the fabric.

Plasma polymerization enables deposition of very thin nanostructured coatings (< 100nm) via gas phase activation and plasma substrate interactions. This dry and ecofriendly technology offers an alternative to replace wet chemical process for surface modification (finishing) of textiles. Plasma polymerization can impart a wide range of functionalities such as water repellency, hydrophilicity, dyeability, conductivity and biocompatibility due to the nano scaled modification of textiles and fibers.

The principle underlying the use of phase change materials is applicable to textiles for providing thermal comfort in garments. When a rise in temperature occurs, the PCM microcapsules react byabsorbing heat and storing this energy in the liquefied phase change materials. When the temperature falls again, the microcapsules release this stored heat energy and the phase change materials solidify again. It is now possible to impregnate cotton material with microcapsules containing a small amount of PCM that helps in improving the thermal insulation of fabric through absorption of energy during heating and release of it during cooling. PCM microcapsules could be directly incorporated into fibres and foams or typically applied to fabrics as a coating.

Layer by layer assembly (L-b-L) is a unique technique for the fabrication of composite films and deposition of coatings with nanometer precision. Nano coating of cotton substrate using L-b-L process enables imparting various functional properties on cotton textiles such as antimicrobial , self cleaning, hydrophilicity / hydrophobicity etc. Cotton fibers offer unique challenges to the deposition of nanolayers because of a unique cross-section as well as chemical and physical heterogeneity of its surfaces. Cationic cotton surface has been successfully coated with alternate layers of anionic and cationic polyelectrolytes, *i.e.* poly (sodium 4-styrene sulphonate) and poly (allylamine hydrochloride) using L-B-L technique (Joshi.M).

This paper mainly focusses on nano finishes on cotton textiles that provide soil repellent and antimicrobial properties required for healthcare textiles.

The most important aspect of health care is to provide a conducive and comfortable environment to facilitate the quick recovery of the patient. Microbial contamination of surfaces, including textile fabrics, can lead to information on infections. These hospital acquired infections prolong the healing of patients, and cause potential risks for serious illnesses. The growing public health awareness of the pathogenic effects, malodours and stain formations caused by microorganisms, has increased the need for antibacterial materials in many health care applications. Based on this need, an attempt was made to develop a fabric suitable for health care applications with nano finishes to impart antimicrobial and stain resistant properties

Hundred per cent cotton twill weave fabric and polyester cotton blend was selected for the white coats. For bed sheets, hundred per cent cotton 20s sheeting fabric was selected. The nano form of zinc pyrothine derivative as antimicrobial chemical and nano fluorocarbon derivative as stain resistant chemical were selected in 6 different combinations.

In experimental research design was followed for this study. In the Phase I, the antimicrobial nano chemicals and Stain repellent nano chemicals were optimised and the best performing concentration were taken forward to develop a dual nano finish for the Phase II. In the Phase III the wear study was conducted to understand the human handling factor on performance of the finish.

Assessment of antifungal and antimicrobial activity of dual finished nano fabric : The assessment of antifungal activity of the nano finished fabric against *Aspergillus niger* was evaluated using AATCC – 30 – 2004.

qualitative and quantitative assessment of antibacterial activity of the nano finished fabric was evaluated as per AATCC standard – 147 – 2004 andAATCC 100- 2004 respectively against *Escherichia coli* and *Staphylococcus aureus*. Analysis for Stain resistance assessment of the nano finished fabric was carried out by AATCC 130- 2000 toward blood, medicine and oil stains. The laundering procedure was followed as per AATCC 135 – 2004.

The hospital uniforms and sheets were made from the finished fabric and subjected to washing after each usage in a hospital. The fabric functional properties were assessed after 5 washes, 10 washes and 15 washes.

The antifungal and antimicrobial activity of the samples treated and untreated (control) are presented in table 1.

The fungus *Aspergillus niger* was not developed on all treated fabrics irrespective of the fibre content. The antifungal activity of the treated fabrics against this fungus was excellent even after 15 washes. It indicates that the nano finish applied on fabric is ideal and suitable for adoption in the field of healthcare textiles.

The zone of inhibition against *E.coli* was recorded as 5 mm in case of cotton coat fabric and sheeting fabric. Around 4 mm ZOI was observed for polyester cotton blend fabric. For S. aureus, 6 mm ZOI was recorded for cotton coat fabric and sheeting fabric and 5.5 mm for polyester cotton blend fabric. It was observed that with increase in number of washes the zone of inhibition decreased slightly. The sheeting fabric maintained its antimicrobial activity against *E.coli* even after 15 washes. Further it was noted that the antimicrobial activity was higher against S. aureus compared to *E. coli* for all the three fabrics.

Assessment of stain resistance for blood stains, oil stains and medicine stains : Assessment of stain resistance for the dual nano finished fabric after wear study was carried out according AATCC -130- 2000. The samples were rated on a scale from grade 5 to 1 by comparison between the residual stain on the test specimen with the stains on the stain release replica. Grade 5 represented the best stain removal and Grade 1 to the poorest stain removal.

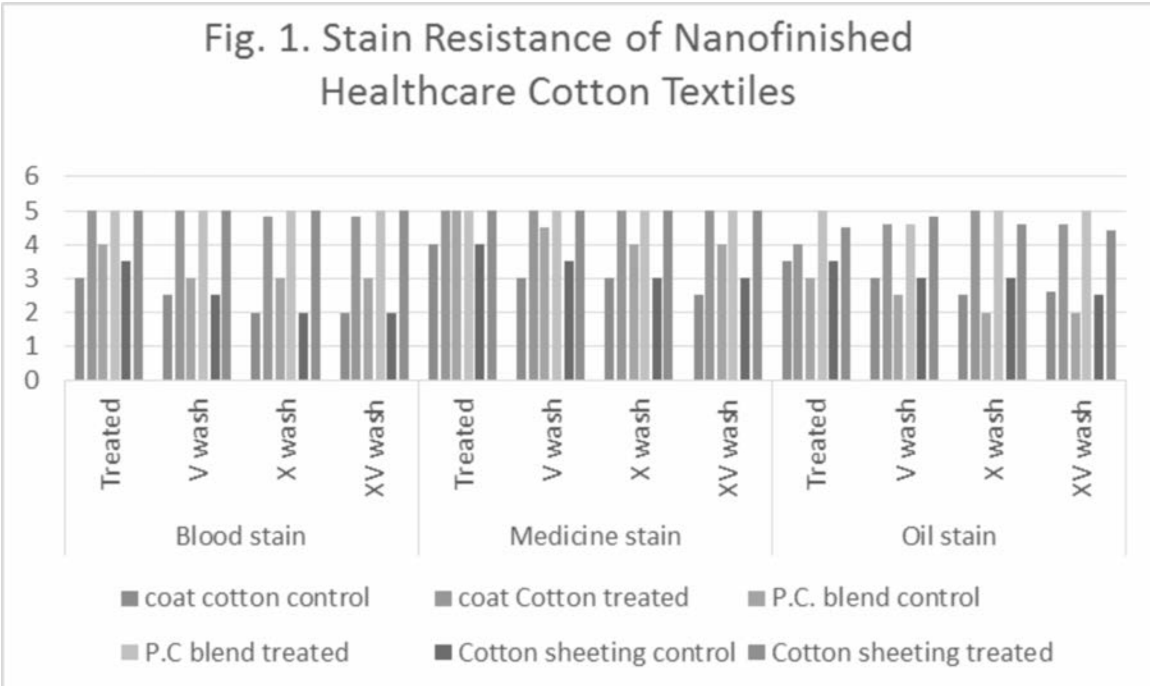
Table 2 depicts the stain resistant property of the dual nano finished fabric after the wear study.

It was observed that the three selected

Table 1. Antifungal and antimicrobial activity of dual finished nano fabric after the wear study against *Aspergillus niger E. coli* and *S. aureus* (zone of inhibition)

Samples	Antifungal activity *Aspergillus niger*				Antimicrobial activity (ZOI)** *E.coli*				*S.aureus*			
	Treated/ un-treated	V wash	X wash	XV wash	Treated	V wash	X wash	XV wash	Treated/ un-treated	V wash	X wash	XV wash
Cotton control	4*	4	4	4	0	0	0	0	0	0	0	0
Cotton treated	0	0	0	0	5	4	4.5	4	6	5	4.5	4
P.C blend control	4*	4	4	4	0	0	0	0	0	0	0	0
P.C blend treated	0	0	0	0	4	3	2	2	5.5	4	3.5	2.5
Cotton sheeting control	4*	4	4	4	0	0	0	0	0	0	0	0
Sheeting treated	0	0	0	0	5	5	5	5	6	5.5	5	4.5

*untreated controls **Zone of Inhibition



fabrics had excellent stain resistance towards blood stains. It was also observed that the fabrics maintained excellent rating (grades) after fifteen washes of wear study as clearly represented in figure 1. Sheeting fabrics in emergency and maternity wards require resistance to blood stains which is a crucial factor for their further use. This showed that the nano finish formulation selected was an appropriate choice for the health care worker's uniform and sheeting.

Similar observations were made with medicine stains. The fabrics maintained excellent rating even after fifteen washes of wear study as clearly indicated in Fig. 2. This showed that the nano finish formulation selected was a pertinent choice for the health care worker's uniform and fabrics.

The resistance towards oil stain was observed to be excellent. The stains were graded as 4 in case of cotton coat fabric, grade 4.5 in sheeting and grade 5 in polyester cotton blended fabric. Not much difference was found in the rating of all the three fabrics after the wear study

Table 2. Stain resistant property of dual finished nano fabric for the wear study towards blood, medicine and oil stains

Samples	Blood stain (grade)				Medicine stain (grade)				Oil stain (grade)			
	Treated/	V wash	X wash	XV wash	Treated	V wash	X wash	XV wash	Treated	V wash	X wash	XV wash
Cotton control	3	2.5	2	2	4	3	3	2.5	3.5	3	2.5	2.5
Cotton treated	5	5	4.8	4.8	5	5	5	5	4	4.6	5	4.6
P.C blend control	4	3	3	3	5	4.5	4	4	3	2.5	2	2
P.C blend treated	5	5	5	5	5	5	5	5	5	4.6	5	5
Cotton sheeting control	3.5	2.5	2	2	4	3.5	3	3	3.5	3	3	2.5
Sheeting treated	5	5	5	5	5	5	5	5	4.5	4.8	4.6	4.4

and after subjecting to fifteen washes.

The cost of production of these experimental dual nano finished fabrics was estimated to be 20 to 25 per cent higher than the unfinished fabrics. But it can be reduced to 10 to 12 per cent in bulk production.

CONCLUSION

Cotton textiles after treatment with nano dual finish containing nano chemicals exhibited good antimicrobial and stain resistance. As the finish is durable upto 15 washes, the finished fabric will be an ideal healthcare textile that control the infections in hospitals.

REFERENCES

Joshi.D., 2014. Ph.D thesis, PJTSAU, Hyderabad

Joshi. M., www.nasi.org.in/Nano/15%20-%20Mangla%20Joshi.pd

Roshan Paul, 2015, Functional Finishes for Textiles: Improving Comfort, Performance and Protection, The Textile Institute, Elsavier Ltd.

INVITED PAPERS

7

Genetic enhancement in cotton through conventional and genetic engineering approaches

O. P. TUTEJA

Central Institute for Cotton Research, Regional Station, Sirsa-125055

E-mail : optuteja2001@yahoo.co.in

Genetic enhancement is necessary and useful but it is not yet well recognized as being so. This is evident because there is no group of scientists or professionals who call themselves "Genetic Enhancers", or "pre-breeders. Genetic enhancement, up to now, has utilized standard hybridization, segregation, and whole plant selection techniques. Back crossing, population improvement, and pedigree selection among selfed progeny are examples of methods employed. But with the advent of molecular genetics and cell biology, a new kind of biotechnology assisted genetic enhancement or pre-breeding is possible. Therefore, unavailable genes for insect resistance or other characters like abiotic stresses may be transferred from alien species into elite genotypes"

The genetic enhancement or pre-breeding refers to the transfer of gene or gene combinations from wild or cultivated sources into breeding materials. The concept emphasizing the use of plant generic resources refers only to the improvement of germplasm. The improved germplasm lines can readily be used in breeding programmes for cultivars development. Therefore pre- breeding does not differ significantly from general framework of plant breeding and is considered as a prior step of sustainable breeding programme. In pre-breeding a useful character is identified from genetic diversity and putting those genes in to useful form. Then the question arises why we need genetic enhancement or pre breeding?

Need for genetic enhancement or pre breeding To meet the ever increasing market demand, plant breeders have to develop cultivars, by using the diverse germplasm lines or elite breeding material. In the past most of the cotton cultivars have been developed through selection and adaptation rather than through creating variability. This has resulted in narrowing down of genetic base resulting in slow progress in plant breeding and increased risk of genetic vulnerability. The best example in cotton is that several resistant/tolerant varieties of upland cotton in north zone like RS 875, RS 810, Rs 2013, F 1861, H1117, H1226 and hybrids like LHH 144, CSHH 198, CSHH 238 and CSHH 243 were developed in north zone by SAU's and ICAR institutes (Ajmera *et al.,* 2004., Tuteja *et al.,* 2005, 2006 and 2009), however, these cultivars have become susceptible over the years due to new strains of begomovirus causing CLCuV (Monga 2014). In order to break these bottlenecks and to create the genetic variability for different characters genetic enhancement or pre- breeding is required to the value of cotton germplasm lines.

Germplasm and genetic enhancement in cotton : Germplasm plays an important role in improving the cotton varieties for resistance to biotic stress and abiotic stresses. Genetically enhanced germplasm lines are also needed for improving the quality characters especially the strength keeping in view the present requirement of modern textile industry. It can be used for development of early maturing genotypes having synchronous boll bursting, which can fit well for High Density Population System (HDPS) suitable for machine picking. Wild germplasm lines can be used for development of male sterile lines and restorer lines for heterosis breeding programme as well as in broadening the genetic base of cultivars, creating vast genetic variability and in value addition of different genotypes.

(i) Use of exotic germplasm : It refers to all the germplasm that do not have immediate usefulness without selection or adaptation in a given environment. (Haullauer and Miranda, 1981). Exotic germplasm has to go under pre-breeding to find its usefulness in breeding programme. Because most of the plant breeders fear using exotic material due to its detrimental effects on elite breeding material (Kannenberg and Falk, 1995). The major constraints in use of exotic germplasm lines are linkage of undesirable genes with desirable traits is a major constraint to increase the utilization of exotic germplasm, introduction of inferior alleles and disruption of co adapted alleles in elite breeding material. Crossing with exotic material can negatively affect adaptedness when introduced into locally adapted gene base. Therefore exotic germplasm has to undergo conversion or pre breeding to find its best use in breeding program.

(ii) Use of wild species of *Gossypium* genome : The genus *Gossypium* contains about 50 species, including diploids (2n=2X=26; genomes A-G and K) and tetraploids (2n=4x=52; genomes AD1-AD5). The wide geographical distribution of the diploid cottons under primitive or traditional cultivation has provided opportunity for the development of extensive diversity in biotic resistance (Stewart and Robbins, 1994). *Gossypium* species and their interspecific hybrids provide an array of plants that display novel chemistries and resistance characteristics that are relevant to protecting cotton from pests (Bell *et al.*,1994). However, the tetraploid cottons have been the major source of new genes that breeders use, but future improvements in agronomic fitness, quality of cotton and environmental resistance depend on diversity within the genetic resources from which new traits can be selected (Stewart, 1995).

India is the only country in the world where all the four cultivated 'A' genome species known as Asiatic cottons (*G. arboreum* and *G. herbaceum*) and tetraploid species of AD genome referred as New World cottons (*G. hirsutum* and *G. barbadense)* are grown. The *G. hirsutum and G. barbadense* originated in the new world from interspecific hybridization between species of closely related to *G. herbaceum* or *G. arboreum* and American diploid *G raimondii* or *G. gossypoides* (Beasley, 1940). Unfortunately, most of these plants cannot be crossed directly to cotton to make fertile hybrids, but must be genetically enhanced before breeders can use them directly.

Gene pools of *Gossypium* : Three types of germplasm namely, primary, secondary and tertiary based on the fact that the ease with which genes can be transferred from the donor source to the recent parent/species (Harlan and Dewet, 1971). The germplasm pools that are centered on cultivated tetraploid and diploid cotton and various *Gossypium* genetic resources available for improvement are assigned according to biological affinity is given in Table 1. Stewart (1995) assigned the *Gossypium* genome groups to primary, secondary and tertiary pools based on the ability to generate fertile hybrids between the donor and recipient species, the frequency of genetic recombination between donor and recipient chromosomes, and the ability to produce stable synthesized allopolyploids its segregation gamete formation and viable progenies, respectively.

In the past primary gene pool has been extensively used for genetic improvement of different crops with a view to create vast genetic variability for various traits in cotton. By crossing the *G. hirsutum*, *G. barbadense* and three wild species *G. tomentosum, G. musterlinum* and *G. darwinii* vast genetic variability has been created for morphological and disease resistance traits such as blight resistance, boll worm resistance, *Fusarium* and wilt resistance , cleistogamy and nectriless leaves (Endrizzi *et al.,* 1985 Meredith 1991, Stewart, 1995).

Recently, the work on use of secondary and tertiary gene pool in cotton has been intensified and as a result vast genetic variability has been created for various economic characters. Because the secondary gene pool species are diploids, the initial interspecific F_1 from a direct hybridization with a tetraploid cotton is sterile triploid with a few exceptions (Meyer, 1974) Successful cases for introgression are fibre strength, disease resistance and cytoplasmic male sterility (CMS) and restorer lines (Stewart, 1995). Similarly, the tertiary gene pool represents the most difficult group of species which include E, C, G and K genomes. The only successful gene transfer from this genepool is the introgression of dominant gene controlling terpenoid aldehyde methylation from *G sturtianum* to *G hirsutum* (Bell *et al.*,1994) which imparts natural resistance against insects and microbial attack.

Methods of genetic enhancement or pre breeding : There are two major approaches for genetic enhancement or pre-breeding either through conventional or genetic engineering methods

(a) Introgression: It is a transfer of one or more genes from exotic/un adapted/wild stocks to the adapted breeding population. This is achieved by crossing donor and recurrent parent. This concept of transfer of character through back cross in cotton was first given by Knight (1945).

In back cross method**,** the parent from which desirable genes are to be incorporated is used as donor parent and the parent which is to be further improved is used as the recurrent parent. Six generations of conventional recurrent backcrossing are levels required to transform a genetic stock. This method leads to accumulation of genes resulting in enhanced level of genetic expression of trait. Various type of back crossing methods are recurrent backcross, inbred backcross, congruity backcross and Marker Assisted Backcross Method (MAS) for genetic enhancement of a germplasm lines.

(b) Incorporation: It refers to a large scale programme aiming to develop locally adapted population using exotic germplasm. In contrast to introgression, incorporation aims at indexing the crop genetic base.

(c) Other breeding approaches: There are other conventional approaches like convergent improvement, modified convergent improvement , strain crossing, multiple strain crossing, development of synthetics/composites, decentralized breeding and participatory breeding for genetic enhancement of a germplasm line

Achievements of genetic enhancement or pre breeding in cotton: Pre-breeding programmes were carried out in USA, China, India and USSR etc during seventies. The important part played by hybridization and introgression in the evolution of new world cotton has been brought out by Hutchinson (1959). The various aspects of gene transfer through introgression in *Gossypium* like disease and pest resistance (Mehetre *et al.,*2002) and fibre quality parameters (Mehetre *et al.,*2003), have been reviewed critically. The potentialities of wild species are given in Table 1.The role of wild species of *Gossypium* as sources of new characters for genetic enhancement has been carried out by several workers and described below:

Improvement in yield: In cotton improvement in yield has been achieved by developing high yielding varieties and interspecific hybrids. In *G. hirsutum* cotton, varieties Arogya, PKV 081, Rajat, Gujarat 67, MCU 2, MCU 5, Deviraj, Devitej, Khandwa 1, Khandwa 2 and Badnawar are derivatives of interspecific hybridization. Commercially cultivated hybrids have been developed both at tetraploid and diploid levels. Varieties like PKV 081 and Rajat have been developed from a cross between *G. hirsutum* x *G. anomalum* (Narayanan *et al.,* 2004.)

Fibre quality traits: The Extra long Staple (ELS) cottons (*G. barbadense*) are known for their superior quality fibres. Besides the ELS cottons, some of wild germplasm also acted as potential source for improving the fibre properties. In Texas, hybridization work involving *G. thurberi* gave successful results in the transfer of high lint strength to upland cotton (Guany, 1952). Kalyanaraman and Santhanam (1955) reported the potentialities of utilizing *G. anomalum* in the transference of low fibre weight with fibre maturity to cultivated *arboreum* varieties. Attempts were also made to utilize *G. anomalum* in the hybridization programme for transference of lint fineness to the cultivated *arboreum* by the above workers and succeeded in isolating some useful types. Marappan (1960) also reported the transference of fineness from *G. anomalum* to the background of *G. arboreum.* A fairly large number of BC_1 F_1 plants indicated the wider scope for recombination and selection of fine linted plants. Similarly Muramata (1969) synthesized hexaploid cotton by crossing *G. hirsutum* and *G. sturtianum* and showed the possibilities of producing spinnable yarn with very high yarn length. Arutyunova and Volkova (1971) attempted the tri-species hybrids by crossing G*. hirsutum* x *G. herbaceum* x *G. harknessi* and recorded very high ginning segregants with 42-43 per cent. Tuteja *et al.,* (2006a) used Introgressed lines as sources for improvement of upland cotton (*Gossypium hirsutum* L.) genotypes for yield and fibre quality traits. Four introgressed lines viz TCH 1648, TCH 1652, TCH 1653 and IH 35 were selected for making crosses with 12 genotypes of upland cotton to explore the possibilities of improving cultivars for seed cotton yield and fibre traits. The cross combinations namely CSH 146 x TCH 1648, CSH 146 x TCH 1652, followed by F 505' x 'TCH 1653', RS 2013 x TCH 1648, RS 2013' x 'TCH 1652' LRA 5166 x TCH 1653, LRA 5166 x IH 35 and F 505 x TCH 1653 showed significantly better performance for seed cotton yield, number of bolls/plant, 2.5 per cent span length and bundle strength.

Table 1. List of *Gossypium* species groped according to germplasm pool by considering tetraploid cotton as cultivated species and having other desirable characters for genetic enhancement

Genepool	Species	Genome	Insect pest resistance	Notes
Primary	*G.hirsutum*	AD_1	*Fusarium* wilt,	Current and obsolete cultivar, breeding stocks, landraces, feral and wild accession
	G.barbadense	AD_2	Blackarm resistance	*Ibid*
	G. tomentosum	AD_3	Drought resistance, thrips	Hawaiian Islands
	G. G.musterlinum	AD_4		NE Brazil
	G. darwinii	AD_5	Bollworms, nematodes,	Galapagos Islands
Secondary	*G. herbaceum*	A_1	Fusarium wilt,	Cultivars, landraces of Africa and Asia Minor, one wild from Southern Africa
	G. arboreum	A_2	*Fusarium* wilt,	Cultivars, landraces from Asia Minor to SE Asia and China; some African
	G. anomalum	B1	Jassid, bollworms, nematodes,	Two subspecies, Sahel and SW Africa
	G. triphyllum	B2	bacterial blight, rust, staple	SW Africa
	G. capitivistridis	B3	length, fibre strength, male	Cape Verde Islands
	G. trifurcatum	B_4	sterility through cytoplasm,	NE Somalia
	G. longicalyx	F_1	Fibre strength, drought resistance,	Trailing shrub, Sudan, Uganda, Tanzania
	G. thruberi	D_1	Bollworms, rust, fibre strength	Sonora Desert, North America
	G. armourianum	D_{2-1}	Jassid, aphids, Heliothis, bacterial blight, gummosis, rust	Baja California (san Marcos Island)
	G. harknessii	D_{2-2}	*Vertcillium* wilt, Fusarium wilt, rust, male sterility through cytoplasm, drought resistance,	Central Baja California
	G. davidsonii	D_{3-d}	Bollworms, bacterial blight,	Southern Baja California
	G. klotzschianum	D_{3-k}		Galapagos Island
	G. aridum	D_4	Male sterility through cytoplasm, drought resistance,	Arborescent, Pacific slopes of Mexico
	G. raimondii	D_5	Thrips, whitefly, bollworms	Pacific slope valleys of Peru
	G. gossypiodies	D_6	Sucking pests	Central Oaxaca, Mexico
	G. labatum	D_7	*Helicoverpa*	Arbores cent, Central Michoacán, Mexico
	G. trilobum	D_8		West central Mexico
	G. laxum	D_9		Arbores cent, Canon del Zopilote, SW Mexico
	G. tumeri	D_{10}		NW Mexico, coastal
	G. schwendimannii	D_{11}		Arborescent, EI Infiernillo Valley, SW Mexico
Tertiary	*G. sturtianum*	C_1	Rust, staple length,	Ornamental, Transcentral Australia arid zone
	G. robinsonii	C_2		Western Australia

	G. bickii	G_1	Bollworms	Central Australia arid zone
	G. austral	G	Lint yield, staple length,	Trans-Australia, north arid zone
	G. nelsonii	G		Central Australia
	G. constulatum	K		North Kimberley (wet-dry tropical), Western Australia Northern NT, Australia
	G. cunnignhamii	K		North Kimberley, W A
	G. enthyle	K		Prostrate, North Kimberley, W A
	G. exgiuum	K		North Kimberley, W A
	G. nobile	K		Trailing, North Kimberley, W A
	G. pilosum	K		North Kimberley, W A
	G.populifolium	K		North Kimberley, W A
	G. pulchellum	K		Prostrate, North Kimberley, W A
	G. rotundifolium	K		North Kimberley, W A
	G. sp. Nov.	K		Arabian Peninsula & Horn of Africa
	G. stocksii	E_1	Staple length, fibre strength, fibre strength, drought resistance	Horn of Africa to Chad
	G. somalense	E_2	Mites, Bollworms	Yemen
	G. areysianum	E_3		Yemen
	G. incanum	E_4		Ethiopia, Somalia, Kenya
	G. benadirense	E		Somalia
	G. bricchettii	E		Somalia
	G. vollesnii	E		
Primitive races				
	Punctatum		Hardiness, resistance to drought, less gossypol jassid, bacterial blight, *Vertcillium* wilt, high lint, strength, fineness,	
	Palmeri, Brasiliense			Sucking pests resistance
	Marie galante		Stem weevil resistance	
	Taxonomic races of *G. hirsutum*			Pink boll worm resistance and high oil content
	Wild accessions of *G. hirsutum*		Boll weevil, *Cercospora* and *Verticillium* wilt resistance	
	Sinense		Wilt tolerance, high fibre length and fineness	
	Cernuuman		High GOT, big boll, long staple, wilt resistance	
	Burmanicum		High fibre length and fineness	
	Bengalense		High ginning, bacterial blight resistance	
	Rozi		Root rot and bollworms tolerance	
	Nadam		Resistance to drought and weevil	

Adopted from Stewart 1995 and Narayanan et al. 2004

Male sterility: The application of CGMS/ Rf system has proved to be an effective means to produce commercial F_1 hybrid seed for many crops (William, 1992). Number of various species imparting male sterility has been reported by several workers. Out of four types of cytoplasmic sources *i.e. G. arboreum, G. anomalum, G. harknessii* and *G. trilobum*, only *G.harknessii* based cytoplasmic male sterility has been more widely accepted and utilized in cotton hybrid program across the world. The first F_1 line of commercial cotton was introduced by crossing an upland cotton (*G. hirsutum*) as a male parent to a wild species *G. harknessii*, (Meyer, 1973). *Gossypium harknessii* Brandagee (D2-2) which is a diploid (2n = 26) was used as female by Meyer (1971) to transfer *G. hirsutum* genome in the cytoplasm of *G. harknessii*. The resultant triploid was made hexaploid (2n=78) using colchicine. Male sterile tetraploid plants were recovered from cross between hexaploid and tetraploids. Another instance of cytoplasmic male sterility was recorded in the diploid Asiatic species (Tayyab, 1982) using the wild species *G. anomalum* as a source for male sterility. It has been reported by Narayanan *et al.,* (2004) that *G. harknessii*, *G. anomalum* and *G. aridum* are the important sources of sterile cytoplasm.

Davis (1979) who studied the A x R and R x B combinations to clearly determine the effect of *G. harknessii* cytoplasm upon the performance of hybrid found no obvious difference between the performance of hybrids carrying either *G. hirsutum* or *G. harknessii* cytoplasm. However, Tuteja *et al.,* (2004) used G. *harknessii* based CMS system in breeding programme and reported that *G. harknessii* cytoplasm source suppresses the yield, ginning, fibre fineness etc. Therefore, the scope of CGMS system will be greater if divergent and stable restorer lines are developed through genetic enhancement or pre breeding.

Development of restorer lines through genetic enhancement: At Central Institute for Cotton Research, Regional Station, Sirsa, 4 CGMS lines viz., CMS SPC 1, CMS SPC 5, CMS SPC 9, CMS SPC 11, were developed using IH 76 carrying *G. harknessii* cytoplasm by back cross breeding. These CMS alloplasmic lines were crossed with restorer euplasmic lines (Cotton Institute Restorers) CIR 7, CIR 9, CIR 20, CIR 26 and CIR 69. The resulting F_1 were selfed to produce F_2. From F_2 onwards the material was handled using Pedigree Breeding approach. The outstanding fertile plants from the segregating generations were selected and selfed and was followed up to F_7 generations. In this way 25 fertility restorer lines namely CIR 97 $P_{1-1,}$ CIR 97 $P_{1-3,}$ CIR 97 $P_{1-4,}$ CIR 97 $P_{2,}$ CIR 97 P_{1-4}, CIR 97 $P_{2,}$ CIR 97 $P_{3-1,}$ CIR 97 $P_{3-2,}$ CIR 97 $P_{3-3,}$ CIR 97 $P_{3-4,}$ CIR 97 $P_{3-5,}$ CIR 119 $P_{1-1,}$ CIR 119 $P_{1-2,}$ CIR 119 $P_{1-3,}$ CIR119 $P_{2-1,}$ CIR 126 $P_{1-2,}$ CIR 126 $P_{2-2,}$ CIR 126 $P_{3,}$ CIR 526 $P_{1,}$ CIR 526 $P_{2,}$ CIR 526 $P_{3,}$ CIR 920 $P_{1-2,}$ CIR 920 $P_{1-3,}$ CIR 926 P_{2-1} and CIR 926 P_{2-3}, were developed which have alien cytoplasm of *G. harknessii* and have the ability of fertility restoration. Parents of restorer lines are indicated in Table 2.These fertility restorer lines were evaluated and characterized on the basis of pollen dehiscence plants were classified as male fertile or male sterile (Tuteja *et al.,* 2006b).

Pest resistance: Cotton crop is attacked by more than 230 species of insects all over the world. In 9 major cotton growing countries 10-15 insects are considered important and 6 species cause major yield losses (Ridgway *et al.,*1994). Therefore the primary objective of genetic enhancement is improving of germplasm lines for resistance against insects by utilizing exotic germplasm. The work of transferring bollworm resistance from *G. thurberi* and *G. armourianum* to Sakel cotton was reported by Knight *et al.,*(1953). Besides that he also attempted to transfer genes for bacterial blight resistance from a *G. barbadense* to upland cotton, Jassid resistance from *G. tomentosum* and boll weevil resistance from *G. armourianum* were transferred to *G. hirsutum.* Sherif and Islam (1970) derived a hexaploid (F_1 *G. hirsutum* x *G.anomalum* doubled) and backcrossed that to *G. hirsutum*. Backcross derivatives were utilized as promising breeding material for jassid resistance. Introgressive breeding proved its potential for developing disease resistant types as well. Black arm resistance has been transferred from *G. arboreum* to *G. barbadense* and rust resistance from *G. raimondii* to *G. hirsutum.* In USSR, an upland variety namely C 4537 resistant to *Verticillium* wilt was isolated from a trispecific cross.

In India Thombre and Mehetre (1981) reported successful transfer of bollworm resistance from *G. thurberi* to *G. hirsutum.* Vroh Bi *et al.,* (1998) introgressed the 'glandless seed and glanded plant' trait from *G. sturtianum* into *G. hirsutum* using *G. raimondii* as bridging

Table 2. Characteristics of newly developed restorer lines.

S.No	Restorer lines	Characters					
		Leaf shape	Leaf surface	Flower colour	Anther colour	Stem colour	Seed fuzz color
1	CIR 97 P_{1-1}	N	H	CF	CC	GP	White
2	CIR 97 P_{1-3}	N	H	CF	CC	GP	White
3	CIR 97 P_{1-2}	N	H	CF	CC	GP	White
4	CIR 97 P_{1-4}	N	GL	CF	CC	RP	Grey
5	CIR 97 P_2	OL	GL	CF	CC	GP	Grey
6	CIR 97 P_{3-1}	N	H	YR	CC	RP	Grey
7	CIR 97 P_{3-2}	N	H	YF	YC	GP	Grey
8	CIR 97 P_{3-3}	N	H	YR	CC	RP	Grey
9	CIR 97 P_{3-4}	N	H	CF	CC	GP	Grey
10	CIR 97 P_{3-5}	N	H	CF	CC	GP	Grey
11	CIR 97 P_{4-4}	N	H	CF	CC	GP	White
12	CIR 119 P_{1-1}	N	H	YF	YC	GP	White
13	CIR 119 P_{1-2}	N	H	YF	YC	GP	Grey
14	CIR 119 P_{1-3}	N	H	CF	YC	GP	Grey
15	CIR119 P_{2-1}	N	H	CF	YC	GP	Grey
16	CIR 126 P_{1-2}	N	H	CF	CC	GP	White
17	CIR 126 P_{2-2}	N	H	CF	LY	GP	White
18	CIR 126 P_3	N	H	CF	CC	GP	White
19	CIR 526 P_1	N	H	CF	CC	GP	White
20	CIR 526 P_2	N	H	CR	LY	RP	White
21	CIR 526 P_3	OL	GL	YF	LY	GP	Grey
22	CIR 920 P_{1-2}	N	H	CF	CC	GP	White
23	CIR 920 P_{1-3}	N	H	CF	CC	GP	White
24	CIR 926 P_{2-1}	N	H	CF	CC	GP	White
25	CIR 926 P_{2-3}	N	H	CF	CC	GP	White

N= normal leaf; OL okra leaf; H= hairiness; GL= glabrous; CF= cream flower; YF= yellow flower; YR = yellow red; CR= cream red; LY light yellow,. RP= Red plant; GP= Green plant; RC= Red colour; YC= yellow colour; CC= cream colour.

species. Konan *et al.,* (2003) reported the introgression of genes for resistance to reniform nematode into *G. hirsutum* using *G. longicalyx* as the donor parent and *G. thurberi* as the bridging species. Badnawar 1, B 1007 and Cambodia-*tomentosum* types such as SRT 1, Khandwa 1 and Khandwa 2 are the resultant progenies from *G. hirsutum* and *G. tomentosum* crosses. These varieties are highly resistant to jassid and have velvet type of hairiness (Narayanan *et al.,* 2004).

Drought tolerance: In upland cotton, resistance to drought has been improved through genetic enhancement of germplasm lines by utilizing *desi* cottons**.** In India drought resistant breeding programmes utilizing the Asiatic cottons were also attempted by many workers which resulted in the infusing of drought resistant genes in hirsutum cotton and the release of varieties like Deviraj (170 CO2), Devitej (130 Co 2 M) and G 67 with wide adaptability (Narayanan *et al.,* 2004).Transferring drought tolerance from *Hibiscus panduraeformis* to *hirsutum* cotton is possible.

Uses of biotechnology in genetic enhancement of cotton : There are two main approaches in biotechnology which are used in pre-breeding

(i) Genetic transformation in cotton: Genetic engineering offers a directed method of pre-breeding that selectively target one or few traits for introduction into the crop plants. The development and commercial released of transgenic cotton plants that have been genetically modified relies exclusively on two basic aspects. The first being the ability to "transform" plant by introducing a gene or genes into cotton genome that are stable transmitted and express in the progeny of subsequent generation. Second gene delivery system for achieving this end is the wildly used *Agrobacterium* mediated transformation method and particle gun bombardment. The second requirement is a need to regenerate fertile plants derived from individual cells.

(ii) Cell culture and plant regeneration for genetic transformation : *In vitro* culture involves intact tissue and organs and, therefore, requires that structural integrity of the tissue is maintained. In the first instance, the objective is usually to induce the structure to develop as good as it would be on the plant. In order to achieve this, individual cells or cell clusters are cultured on nutrient media containing growth regulators. The undifferentiated mass of cells is called callus. A piece of callus is submerged in liquid medium. The cell dissociates from each other and from suspension, which can be used for somatic embryogenesis and plant regeneration. Not only have this development has enabled cotton to be genetically enhanced for desirable traits but has allowed the use of cell and organ culture for understanding basic studies on cotton genetics and physiology also.

iii) Development of transgenic cotton: The era of transgenic cotton began in 1990 with introduction of the *Bt* gene Cry1Ac to develop the first *Bt* cotton variety which showed high level of resistance to *Helicoverpa*. The gene was transferred into the genome of cotton explants using a bacterium called *Agrobacterium tumefasciens*. The transformed cells were developed into a full genetically modified plant now called Bt-cotton. The *Bt* gene from originally genetically engineered mother plant (Coker series) was transferred to advance cotton cultivars through backcrossing. In India the

Table 3. Commercial release of different *Bt* cotton events in India.

S. No	Gene (s)	Event	Developer/company	Year of Approval
1	Cry1 Ac	MON 531	Mahyco/Monsanto	2002
2	Cry1Ac and Cry2Ab	MON 15985	Mahyco/Monsanto	2006
3	Cry1Ac	Event 1	JK Agri Genetics	2006
4	Fused genes Cry1Ab and Cry1Ac	GFM Event	Nath Seeds	2006
5	Synthetic Cry1C	MLS 9124	Metahelix Life Sciences	2009
6	Cry1Ab + Cry2Ae.*	-	Bayer Crop Sciences	-
7.	Cry1Ac + Cry1F*	-	Dow Agri Sciences	-
8.	CP4 EPSPS in Roundup Ready Flex*	-	Mahyco/Monsanto	-

*Not approved for commercial cultivation

transgenic cotton was introduced into cultivation during 2002-2003 first with Bollgard I (Cry1Ac). Currently, Cry1Ac, Cry2Ab and Cry1C have been approved for commercial cultivation in India. *Bt* cotton hybrids available in India are derived from technologies developed by Monsanto (Cry1Ac and Cry1Ac + Cry2Ab), Metahelix (Cry1C), Chinese Academy of Agricultural Sciences through Nath seeds (modified Cry1Ac called as fusion gene) and JK seeds (Cry1Ac). Dow Agro Sciences are conducting field trials with Cry1Ac + Cry1F and Bayer is introducing Cry1Ab + Cry2Ae (Table 3).

The transgenic cottons were all based on proprietary germplasm and hybrids were predominantly of *G. hirsutum* x *G. hirsutum* combinations. As a result, intra *hirsutum* transgenic cotton hybrids are grown in more than 92.0 per cent of the total cotton area of 121.91 lakh hectares (Anonymous, 2014). However, Extensive cultivation of *Bt* transgenic cotton and selection pressure on target insects in a continuous mode will encourage the development of resistance in insects towards *Bt*. Therefore, *Bt* cotton will have to be managed in a way that discourages pest resistances to Bt toxins by genetic enhancement of germplasm lines through gene pyramiding. *e.g.* Monsanto and Dow, together have stacked eight genes into GM Maize called SmartStax. Six of these are for insect control, Cry1A.105, Cry2Ab2 and Cry1F for borers; Cry3Bb1, Cry34Ab1 and Cry 35Ab1 for root worms; pat for glufosinate resistance and CP4 EPSPS for glyphosate resistance. So far 342 *Bt* toxin genes are available for research to develop insect resistant genetically modified crops (Nandeshwar, 2004 and Kranti, 2012). Therefore the cotton genotypes can be genetically enhanced through genetic engineering for various characters by using different genes .

Future prospects for genetic enhancement work : In cotton distant hybridization has played a significant role in transferring the desirable characters like fineness, strength, resistance to pests like jassids and bollworm, black arm, drought resistance and male sterility besides improvement in yield by releasing hybrids. However the utilization of wild germplasm poses the various problems like reproductive barriers such as failure of pollen germination and slow pollen tube growth, elimination of chromosomes, chromosomal abnormalities, hybrid unviability and sterility (Mehetre *et al.,* 2003). Recently, significant advances have been made in overcoming these barriers, therefore the future prospects for genetic enhancement depend on genetic engineering techniques and the wild species of cotton could be looked as a source for the contribution of genes governing the traits like fibre fineness, strength and maturity, biotic and abiotic resistance, increased photosynthetic rate, uniform maturity, etc

Though handy tools in biotechnology are available for gene introgression, it takes a long time compared to the routine hybridization programme owing to the non responding nature of cotton to the nurture given at the laboratories. Similarly, shortfalls are bound to occur in conventional hybridization owing to the disparity in the genome introgressed and genetic disturbances. Therefore there is an urgent need to encourage the Scientists to become "Genetic Enhancer or Pre Breeders" and helping in the breeding programme for development of cultivars to meet the ever increasing need of mankind on the following aspects:

- Development of genotypes suitable for early maturity with synchronous opening suitable for high density population system (HDPS) and machine picking.
- Agricultural biotechnology offers opportunity for development of germplasm lines with higher level of resistance to biotic and abiotic stresses.
- Gene transformation and marker assisted selection are useful tools to overcome the limitations of conventional breeding for the improvement of cotton germplasm lines for useful traits through interspecific hybridization or genes sourced across the species barriers.
- DNA marker assisted selection can be used in early generations to screen large numbers more efficiently.
- For developing multiple adversity resistance (MAR) lines programme in cotton collaborates actively with genome mapping, fingerprinting, gene tagging and transformation.
- Similarly to develop the germplasm lines with multiple insect resistance (MIR) to reduce the expenditure on pesticides. This can be achieved through transfer of morphological and biochemical factors imparting resistance to single genotype.
- Another concept picking up worldwide is the organic farming for which the germplasm need to be screened and genetically enhanced through pre-breeding.

REFERENCES

Ajmera, B. D., Verma, P. C., Gurjar, K. L. and Pundhir, P. 2004. Sources of resistance to cotton leaf curl virus disease. Lead paper presented in National Seminar on *"Cotton leaf curl virus disease"* held at Central Institute for Cotton Research, Regional Station, Sirsa. Pp 69-71.

Anonymous, 2014. *"Annual Report"* All India Co-ordinated Cotton Improvement Project (2014-2015). Pp 2-4.

Arutyonova, L. G. and Volkova, L. A. 1971. Behaviour of chromosomes in meiosis of a hexaploid cottom amphidiploid (*Gossypium*). *Genetika* **7**: 148-52

Beasley, J. O. 1940. The origin of American tetraploid *Gossypium* species. *Am. Nat.* **74:** 285-86.

Bell, A. A., Stipanovic R. D., Mace, M. E. and Kohel, R. J. 1994 Genetic manipulation of terpenoid phytoalexins in *Gossypium* effects on disease resistance. In: B.E. Ellis, G.W. Kuroki and H.A. Stafford (Eds), Genetic

Engineering of plant Secondary Metabolism, New York. Pp 231-249.

Davis, D. D. 1979. Synthesis of commercial F_1 hybrids in cotton II. Long, strong-fibre *G.hirsutum* L x *G. barbadense* L. hybrids with superior agronomic properties. *Crop Science* **19**: 115-16.

Endrizzi, J. E., Turcotte, E. L. and Kohel, R. J.1985. Genetics, cytology, and evolution of *Gossypium. Adv. Agron.* **23**: 271-375.

Guany, R. L. 1952. Impressions of American Cotton Research. *Emp. Cott. Gr. Rev.* **XXIX,** 171-81.

Hallauer, A.R. and Miranda, J.B. 1981. Quantitative Genetics in Maize Breeding. Iowa State University Press, Ames, Iowa.

Harlan, J. R. and Dewet, J. M. J. 1971. Towards a rational classification of cultivated plants. *Taxon.* **20**: 109-517.

Hutchinson, J. B. 1959. The application of genetics to cotton improvement. Cambridge Univ, Pr., London.

Kalyanaraman, S. M. and Santhanam, V. 1955. A note on the performance of some interspecific involving wild species of *Gossypium*. I. *Arboreum- Anomalum* crosses. *The Indian Cotton Crossing Review* **11**: 136-40.

Kannenberg, L.W. and Falk, D.E. 1995. Models for activation of plant genetic resources for crop breeding programs. *Canadian J. Plant Science.* **75:** 45-53.

Knight, R. L. 1945. The theory and application of the backcross technique in cotton breeding. *J. Genet.* **47**: 76-86.

Knight, R .L., Dark, S. O. S. and Euany, R. L .1953. Progress report from Experimental Stations (1951-52). E.C.G.C. 10-16.

Konan, O. N., Ruano, O., Prudhome, S., Bandoin, J. P. and Mergeai, G. 2003. Introgression in tetraploid cotton of resistance to the reniform nematode, *Rotylenchulus reniformis* lind. And Oliveila, from the *Gossypium hirsutum* L. x *G. longicalyx* x hutch Lee x *G. thurberi* Tod trispecific hybrid. Paper presented at *"World Cotton Research Conference-3"*, Cape Town, South Africa.

Kranti, K. R. 2012. *Bt* cotton Question and Answers. Published by The Secretary Indian Society for Cotton Improvement, Central Institute for Research on Cotton Technology Adenwala Road, Matunga, Mumbai.

Marappan, P. V. 1960. Cotton improvement through interspecific hybridization: Behavior of *arboreum- anomalum* back crossing. Dissertation submitted to the University of Madras as part fulfillment for the award of Masters Degree.

Mehetre, S. S., Gawande, V L., Aher A. R and Shinde G. C. 2003. Cytomorphology of interspecific hybrids between *Gossypium hirsutum* L., its haploid and *Gossypium raimondii. Indian J. Genet.* **63 :** 319-24.

Mehetre, S. S., Patil, S. D. and Gawande, V. L. 2002. Introgression of disease and pest resistance from wild to cultivated species of *Gossypium*-a review. *J. Cotton Res. Dev.* **16**: 178-81.

Meredith, W.R. J. 1991. Contribution of introduction to cotton improvement. In: H.L.Shands and L.E Wiesner (Eds), *"Use of plant Introductions in Cultivar Development"*, Crop Science Society of America. Madison, Wisconsin. Pp. 127-46.

Meyer, V. G. 1971. Cytoplasm effects on anther number in interspecific hybrids of cotton. *Journal of Heredity* **62**: 77-78.

Meyer V. G. 1973. Fertility restorer genes for cytoplasmic male-sterility from *Gossypium harknessii*. Beltwide Cotton Prod. Res. Conf. Proceedings.Pp 65.

Meyer, V. G. 1974. Interspecific cotton breeding. *Econ. Bot.* **28**: 56-60.

Monga, D. 2014. Cotton leaf curl virus disease. Central institute for Cotton Research Regional Station, Sirsa (Haryana). Technical Bulletin No. **2**/2014.

Nandeshwar, S. B., Moghe Sandhya and Dongre A.B. 2004. Transgenic cotton-Indian perspective. Proceedings of National Symposium on *"Changing World order- Cotton Research Development and policy in context"* held at Acharya N. G. Ranga Agricultural University, Hyderabad.Pp78-83.

Narayanan, S. S., Singh,V.V., Mohan Punit, and Gotmare, Vinita. 2004. Germplasm and its utilization in cotton improvement- retrospect and prospects. In: Recent Advances in cotton research and development in India. National Symposium on *"Changing World Order – Cotton Research, Development and Policy in Context"* at Acharya N.G. Ranga Agricultural University, Hyderabad. Pp,3-24.

Ridgway, R.L., Inscoe, M. N. and Thorpe, K. W. 1994. A Biologically Based Pest Controls: Markets, Industries, and Products,@ Special Report for OTA, U.S. Dept. Agr., Agr. Res. Serv., May 20.

Sherif, A. and Islam, A. S. 1970. Cytogenetic studies of some back cross derivatives of *Gossypiumhirsutum x G. anomalum* . *Can. J. Genet. Cytol.* **12**: 454-60.

Stewart, J. McD 1995. Potential for crop improvement with exotic germplasm and genetic engineering. In: Constable Git, Forrester N.W (eds) Challenging the future. *"Proceedings of the World Cotton Research Conference – 1, CSIRO"*, Melbourne. Pp. 313-327.

Stewart, J.M. and Robbins, R.T.1994. Evaluation of Asiatic cottons for resistance to reniform nematode. In: Oosterhius DM, editor. *"Proceeding 1994 Cotton Research Meeting"*, Special Report 166. Fayetteville, AR: Arkansas Agricultural Experiment Station; 1995. Pp. 165–168.

Tayyab, M. A. 1982. Strategy in crossing yield barriers of *arboreum* cotton. Seminar on cotton, Haryana Agricultural University, Hissar.

Thombre, M. V. and Mehetre, S. S. 1981. Interspecific hybridization in *Gossypium* L. ll. Cytomorphological studies in hybrid *G. hirsutum* haploid 2n=2x=26, (A_hD_h) X G. *thurberi* (2n=2x=26, D_1D_1). *Cytologia* **46**: 291-99.

Tuteja, O. P., Khadi, B. M., Monga, D., Ahuja, S. L., Verma, S. K., Meena. R. A., Jeyakumar, P. and Kumar, S. 2006. CSHH 238- A high yielding cotton hybrid for north zone. *J. Indian Soc. Cotton Improv.* **31**: 105-11.

Tuteja, O. P., Khadi, B. M., Monga, D., Verma, S. K., Ahuja, S. L., Meena. R. A., and Kumar, S. 2009. CSHH 243- A quality cotton hybrid for north zone. *J. Indian Soc. Cotton Improv.***34**: 38-41.

Tuteja, O. P., Kumar, Sunil and Singh, Mahendar. 2004. Identification of new fertility restorers based on cytoplasmic male sterility system in cotton (*G. hirsutum*). *International Symposium on Strategies for Sustainable Cotton*

Production~ A Global Vision 1. Crop Improvement, 23-25 November 2004, University of Agricultural Sciences, Dharwad. Pp. 107-111.

Tuteja, O. P., Kumar, Sunil, Singh, Mahendar and Khadi, B.M. 2006a. Identification and characterization of new fertility restorers in cytoplasmic genetic male sterility (CGMS*)* of cotton [*Gossypium hirsutum* (L.)] derived from *Gossypium harknessii. Indian J. Genet.* **66**: 53-54.

Tuteja, O. P., Monga, D., Verma, S. K., Meena. R. A., Jeyakumar, P., Singh, P., Kumar, S. and Singh, M. 2005. Shresth (CSHH 198**)-** A quality cotton hybrid for north zone. *J. Indian Soc. Cotton Improv.* **30** : 115-19.

Tuteja, O. P., Singh, Mahendar, Verma S. K. and Khadi B. M. 2006b. Introgressed lines as sources for improvement of upland cotton (*Gossypium hirsutum* L.) genotypes for yield and fibre quality traits. *Indian J. Genetic.* **66**: 251-52.

Vroh, Bi. I., Baudin, J. P. and Mergeai, G. 1999. Development of high-gossypol cotton plants with low-gossypol seeds using trispecies bridge crosses and in vitro culture of seed embryos. *Euphytica* **106:** 243-51**.**

Williams, M.E.L.C.S., III, 1992. Molecular biology of Cytoplasmic Male Sterility, in *Plant breeding Reviews*, edited by J. Janick. Jonh Wiley and Sons, Inc., New York. pp. 23-51.

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Wide hybridization in cotton – Problems and prospects

PANKAJ RATHORE, DHARMINDER PATHAK, HARPREET KAUR AND R.K. GUMBER

Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana - 141 004

E-mail : pankaj@pau.edu

Cotton, is one of the most important commercial crops, enjoys a pre-eminent status among all the cash crops in the country and elsewhere which has been recognized as a vital component of the global economy (Arpat *et al.,*., 2004). Cotton is a crop of prosperity having profound influence on man and matter. Currently *Gossypium* includes 50 species spreading over eight genomic groups ('A' through 'G' and 'K'), four of which are cultivated, 43 are wild diploids and three are wild tetraploids (Percival and Kohel, 1990). Out of the four cultivated species, *Gossypium hirsutum* L. and *Gossypium barbadense* L. commonly called as new world cottons are tetraploids (2n = 4x = 52), whereas *G. herbaceum* L. and *Gossypium arboreum* L. are diploids (2n = 2x = 26) and are commonly known as old world cottons. Earlier, five allopolyploid species were widely recognized, but a sixth tetraploid species *viz., G. ekmanianum* Wittm. was recently resurrected and subsequently validated (Grover *et al.,* 2015) by molecular sequence data.

Evolution of cultivated allopolyploids in different crops are first standard examples of cross between different diploid species. Species belonging to 'A' genome have been known as only fibre yielding among diploids. Two tetraploid species, *G. hirsutum* and *G. barbadense* known for cultivation were known to be evolved naturally from cross between *G. herbaceum* subsp. *africanum* (AA) and wild diploid, *G. raimondii* (DD) (Hutchinson, 1959; Douglas and Brown, 1971 and Phillips, 1974). They have been known for higher *kapas* yield as well as superior fibre quality than old world diploid cottons. *G. hirsutum* is susceptible to many biotic and abiotic stresses and genetic diversity among modern upland cotton cultivars is limited, as revealed by isozyme analysis (Wendel *et al.,* 1992) and various DNA markers including RFLP (Brubaker *et al.,* 1993; Brubaker and Wendel 1994), RAPD (Iqbal *et al., 1997*; Linos *et al.,* 2002), AFLP (Abdalla *et al.,* 2001; Iqbal *et al.,* 2001), and SSR (Lacape *et al.,* 2007, Fang *et al.,* 2013). Increasing upland cotton diversity is essential for genetic improvement. A very few of the wild species grow together in the wild, and not surprisingly therefore, documented cases of hybridization and introgression are rare (Wendel and Grover 2015). Extensive genetic variation is available among members of the genus *Gossypium* (Percival and Kohel 1990), and efforts to increase the genetic base of *G. hirsutum* can draw upon the wild species of *Gossypium*. The wild and cultivated diploid species have wide adaptability and high degree of resistance to biotic and abiotic stresses (Patel and Mehta 1990). Wild species have been utilized to transfer the resistance to various insect-pests and diseases including cotton leaf curl disease for improving the cultivated cotton species especially *G. hirsutum* (reviewed by Mehetre *et al.,* 2002c). Many reports can be found wherein researchers have been trying to produce the new polyploid species and/or introgresssing the genes from the wild to the cultivated *Gossypium* species for increasing the diversity in the modern cultivars (Ahmad *et al.,* 2011, Nazeer *at al* 2014, Zhang *et al.,* 2014, Liu *et al.,* 2015 and Mehetre *et al.,* 2009). The characterization of interspecific hybrids is another aspect of the biological research. Morphological and molecular characterization of the genotypes reveal the various genetical and epigenetical phenomena and helps in understanding inheritance of various traits as well.

Plant breeders have used unadapted germplasm, almost exclusively, as a source of major genes for insect and disease resistances and have mostly relied on repeated intercrossing of adapted elite genotypes for improvement of yield (Fulton *et al.,*, 2002).

Heterosis has been exploited in large number of crop plants. India has been a leader in the development and commercialization of cotton hybrids. The first interspecific (*G. hirsutum* x *G. barbadense*) hybrid Varalaxmi was released during 1971 (Katarki 1971). Later on, a series of hybrids *viz.,* DCH 32, HB 224, DHB 105 etc have been developed. Interspecific crosses involving *G. arboreum* x *G. herbaceum* have also been developed and released. Examples include G Cot DH 7 and DDH 2.

Interspecific hybridization of *G. hirsutum* x *G. barbadense* followed by selection in the segregating generations has led to the development of many improved cultures. Varieties MCU 2 and MCU 5 of *G. hirsutum* x *G. barbadense* cross are the successful examples. Similarly, *G. arboreum x G herbaceum, G arboreun x G anomalum, G herbaceum x G anomalum* are most exploited cases for fibre quality improvement. For example in AK 8401 (*G. arboreum*) fibre length was improved through introgression with *G. anomalum* (Kulkarni *et al.,*, 2001).

Many breeding stocks as well as varieties have been evolved so far through interspecific hybridization involving wild species. Genes for lint strength from a lintless wild species *G. thurberi* have been transferred into cotton. A triple hybrid [(*G. thurberi* Tod. × *G. arboreum* L.) × *G. hirsutum* L.] was first utilized as a genetic source for higher fibre strength (Beasley, 1940). In India, a *hirsutum* variety Arogya was developed through *hirsutum* × *anomalum* hybridization programme at CICR, Nagpur and was released for rainfed conditions in the Central Zone of India. Immunity to bacterial blight and tolerance to sucking pests were introgressed into this variety from the wild species *G. anomalum.*

Successful introgressions between *G. arboreum* and *G. hirsutum* have been reported (Deshpande *et al.,*, 1992; Kulkarni and Khadi, 1998; Deshpande and Baig, 2001). DLSA 17, an *arboreum* variety with better fibre quality has been released. Deshpande and Baig (2001) have reported the identification of segregants with increased boll weight, staple length and ginning outturn derived from interspecific crosses of *G. arboreum* and *G. hirsutum.*

Patel and Desai (1963), with an objective of improving local *G. herbaceum* types for quality characters used the Persian-211(*G. barbadense*) for crossing with improved *G. herbaceum* strains at Surat and synthetic cultures *viz.,*, 1802, 1773, 1777, 1789 and 1799 were derived from the cross (1027 ALF x Per 211) FI x 1627 A.L.F. Which possessed ginning outturn ranging from 26.1 to 40.1 per cent, fibre length ranging from 0.98" to 1.14" but, were low in yield in comparison with the local improved strains. They were therefore further crossed with the promising Surat and Buroach types to improve their yield and as a result some of the promising ones possessing good combination of yield, ginning outturn and fibre qualities were obtained. Ramachandran *et al.,*. (1964) developed hybrids involving *G. anomalum* with *G. arboreum* cultures like, 5001, 6874 and B-32-48. The results were assessed in the first and second back crosses and also in the straight crosses of the above hybrids in the advanced generations. The composite samples of lint of selected families showed the fibre weight to be 0.213 millionth of an ounce per inch compared to 0.200 for *G. arboreum*, a pressely strength index of 8.94 lb/mgm compared to 7.8 lb/mgm for *G. arboreum*. In the progeny of the hybrid BC_2F_2 of 6874 x *G. anomalum,* a pressley strength index of as high as 9.82 lb/mgm and fineness of 0.093 millionth of an ounce per inch were recorded.

Katarki (1971) carried out the interspecific hybridization between *G. hirsutum* x *G. barbadense* and evolved the first commercial interspecific hybrid, Varalaxmi. It showed superior fibre quality characters like fibre strength (44.8 at 'o' guage), fibre fineness (3.2 micronaire) and fibre length (32.7 mm). Later he released another high yielding interspecific hybrid DCH-32 which was superior to Varalaxmi in yield potential and ginning out turn. Hyer (1973) derived nearly isogenic lines from the sixth back-cross generation of 41- 63 x Acala 4-42-77 back-crossed to Acala 4-42-77. He reported that the glanded and glandless lines were similar in fibre properties but the lint yield of the glandless line was lower than that of the glanded line. The genes gl2 and gl3 (both for glandlessness), or genes closely linked to these therefore appear to depress lint yield without affecting fibre properties.

Meyer (1974) transferred characters such as nectariless from *G. tomentosum*, fibrous root character from *G. sturti*, increased fibre strength from *G. thurberi*, bollworm resistance from *G. anomalum* and cytoplasm of *G. tomentosum*, for development of male sterile hybrids into cultivated tetraploid, *G. hirsutum.* Nectarilessness is a necessary character to prevent outcrossing and impart pest tolerance. Meyer and Meredith (1978) were able to transfer nectarilessness character from *G. tomentosum* to upland cotton and cultures were popularised as DESTOM16. *G. herknessii, G. aridum* and *G. trilobum* have been used as donors for cytoplasmic-genetic male sterility system. However, due to yield penality, these systems have not been commercialized so far.

Niu *et al.,* (1998) used two cultivated species (*G. hirsutum* and *G. arboreum*), four wild species (*G. thurberi*, *G. anomalum*, *G. sturtianum* and *G. bickii*) and one semi-wild species (*G. mexicanum*) to create 76 new germplasm lines of nine types through various methods of hybridization, *in vitro* culture, selection, identification and multiplication. These lines have various desirable characteristics including high fibre quality (specific strength and fineness higher than those of the current popular varieties). They reported that some lines (BZ701-712) had a span length of 33.4-37.7 mm and some lines (BZ901-903) were very early having a growth period of 100-115 days.

Katageri *et al.,* (2004) reported the results of interspecific hybridization using *G. barbadense* as donor and *G. herbaceum* and *G. arboreum* as recipient parents. Selected recipient plants of Jayadhar possessed fibre lengh of 24 – 26 mm, fibre strength of 20 – 23 g/tex as against 22 mm and 16 g/tex of Jayadhar. Similarly, selected A-82-1 *arboreum* plants had fibre length 24 mm and 25 g/t against 16 mm and 13g/t of the recipient. Plants with 24 g per tex fibre strength and 28 mm fibre length were isolated in F_3 from cross between *G. hirsutum* var. Abadhita x (G.cot- 11 x *G. tomentosum*) by Soregaon (2004).

Ahton *et al.,* (2003) investigated mating schemes to achieve *G. sturtianum* and *G. australe* diploid cottons into tetraploid *G. hirsutum.* They were able to obtain seven different single chromosomes of *australe* in *hirsutum* background. These lines constitute valuable materials for carrying out fundamental and applied genetic investigations.

Pima cottons possess superior fibre properties than the upland cottons. Saha *et al.,* (2004) reported the development of substitution lines in the *hirsutum* background where a chromosome/chromosome arm of *hirsutum* genome was substituted by a corresponding chromosome/chromosome arm of *barbadense* genome. The lines with substitutions for chromosomes 15, 18, 14sh and 22sh had reduced seed cotton yield and lint yield. Lines with alien chromosomes 2, 6, 16, 18, 5sh, 22Lo, and 22sh had improved lint percentage. Lines with substitution of chromosome 25 had reduced micronaire and increased fibre length. All the substituted chromosomes except 2,4 and 6 had reduced boll weight. Lines with substituted 14sh, 15sh and 25 had increased fibre length. The results provided information on the association of specific chromosomes with genes agronomic and fibre traits. These new genomic resources will, provide additional approaches for improvement of upland cotton and will enable the development of chromosome specific recombinant inbred lines for higher resolution mapping.

Bacterial blight resistance from *G. anomalum* to *G. hirsutum* in the form of short duration short staple drought tolerant variety Arogya which was released for cultivation in the Vidharba region (Gotmare *et al.,*, 2004).

Besides lint, cottonseed is also an important source of edible oil. Cottonseed oil is composed of three fatty acids *viz.,*, linoleic acid, olic acid and palmitic acid and two minor fatty acid namely myristic and stearic acids. Gossypol has to be removed from the oil that increases the processing cost. Gossypol is considered to impart resistance/tolerance to some insect pests. Therefore, it would be desirable to have plants with gossypol present in the shoot but absent in the seeds. Vroh *et al.,* (1999) synthesized two trispecies hybrids *G. thurberi - G.sturtianum - G.hirutum and G. hirsutum – G. raimndii – G. sturtianum.* Backcrosses with the *hirsutum* parent were made. The gland levels in the backcrossed seeds ranged from glandless seeds to normally glanded seeds. All vegetative parts of those hybrids were glanded, but a wide range of variability for gland density was observed on leaf stem, bract and calyx. Plants derived from seeds having a reduced level of gossypol constitute very interesting germplasm to develop cultivated glanded cotton with low gossypol seeds.

Mehetre (2010) introgressed successfully the desired traits like fineness and strength, non-convoluted and fully thickened with secondary cellulose deposition and thinnest fibre from wild *Gossypium anomalum* into cultivated varieties blending both conventional and nonconventional techniques. The recovered transgressive segregants would afford vast opportunities in selecting plants with desired attributes from segregating populations and introgression of genes from wild *Gossypium anomalum* to commercial cultivars.

Another study attempted to explore the possibility of successfully transferring the jassid resistant genes from two wild cotton species *G. armourianum* and *G. raimondii* into the cultivated *G. hirsutum* genotypes through backcrossing and colchiploidy (Pushpam and Raveendran 2006). The percentage of boll set was maximum in the cross *G. hirsutum* x *G. raimondii* (14.3%) and minimum in the cross *G. hirsutum* x *G. armourianum* (7.5 %). Viable seeds were obtained in all combinations indicating the compatibility between all the *hirsutum* lines with the wild species *G. armourianum* and *G. raimondii*. The hybrids between *G. hirsutum* x *G. armourianum* and *G. hirsutum* x *G. raimondii* involving wild species as seed parents were highly sterile. Also there was no boll set on self-pollination as well as backcrossing with the cultivated parent. Although about 3400 crosses were effected, no boll setting was observed. Nevertheless, in reciprocal backcrosses when the F_1 was used as pollen parent on *G. hirsutum* female parents, a few bolls were obtained.

Sacks and Robinson (2009) introgressed resistance to *Rotylenchulus reniformis* into the cultivated tetraploid species *G. hirsutum* through crossing a resistant diploid A_2-genome *G. arboreum* with a hexaploid *G. hirsutum*/ *G. aridum* bridging line $2[(AD)_1D_4]$ to obtain a tetraploid triple species hybrid.

Nazeer *et al.,* (2014a) explored the possibility of transferring virus resistant genes from the wild species *G. stocksii* into *G. hirsutum*. Interspecific F_1 hybrid between the two species was produced after attempting 438 pollinations. 3.4 per cent boll setting and 42.9 per cent germination was obtained during this hybridization programme. F_1 seeds were treated with 0.03 per cent colchicine to obtain hexaploid plants with the success rate of 33.3 per cent. The F_1 population did not show any symptom of Cotton leaf curl disease (CLCuD) in the field, tested by grafting with CLCuD susceptible rootstock. It was concluded that it is possible to transfer CLCuD resistance and high fiber strength from *G. stocksii* to *G. hirsutum*.

A new synthetic allotetraploid ($A_1A_1G_2G_2$) between *G. herbaceum* and *G. australe* was produced by Liu *et al.,* (2015) to transfer "Glandless-seed and Glanded plant" trait to the upland cotton in a period of 9 years. A total of 16 putative hybrid seeds were obtained from 200 pollinated flowers and planted in 2007. At the maturity stage, only one plant resembled *G. australe*, which was a putative F_1 interspecific hybrid ($2n = 2x = A_1G_2 = 26$). The putative interspecific F_1 hybrid plant appeared to be highly male and female sterile, as no pollen was released and no bolls were produced when the plant was pollinated by *G. herbaceum*. The sole putative hybrid plant was propagated by grafting and treated with 0.10% colchicine for 24 h during squaring stage. In the sixth year, one branch of the hybrid plant had produced three bolls and a total of 19 S_1 seeds were obtained from these bolls by self-pollination in 2012. This interspecific tetraploid hybrid had partial fertility. In 2013, S_1 seeds (derived from the grafted hybrid F_1) were planted on soil in small plastic pots. One S_1 plant was rescued which set five bolls to give 22 seeds, while the other two S_1 seedlings. In 2014, S_2 seeds were planted. The interspecific incompatibility, to some extent, had been alleviated in the S_2 generation. Both S_1 and S_2 were new synthetic allotetraploid plants.

According to Anjum *et al.,* (2015), there is no resistant genotype in upland cotton to CLCuD, the only way is to introgress this resistance in upland cotton from wild species. 30 *Gossypium* species were screened for resistance to CLCuD and ten diploid species were found to be resistant to Burewala strain of cotton leaf curl virus. They reported that material with good fibre quality traits and resistance to various insects and pests is being developed using wild diploid species.

A project is underway across many centres in the country for the enhancement of fibre quality in *desi* cottons. As a result, many cultures with superior fibre properties and acceptable yield level have been developed.

Cotton leaf curl disease (CLCuD) is a serious threat to American cotton cultivation in the north Indian cotton growing states of Punjab, Haryana and Rajasthan. Heavy yield losses due to CLCuD have been reported especially if the disease appears at an early stage of crop growth. *G. arboreum* possesses high degree of resistance to this dreaded disease and can serve as an important donor for the transfer of CLCuD resistance into American cotton. At PAU, crosses between *G. hirsutum* (AADD) x *G. armourianum* (DD) have been attempted and efforts are underway to induce amphidiploidy in the resulting sterile triploid hybrid.

Fertilization barriers in interspecific crosses and subsequent generations : A major objective in most of breeding programs is to generate the genetic variability for improving economic traits of crop. Hybridization among species and between species generates considerable amount of genetic variation, which could be used for further selection of desirable traits. But, several pre and post-zygotic barriers prevent the successful gene transfer from wild to cultivated species reviewed by Mehetre *et al.,* (2002a).

Failure of pollen germination is an important incompatibility barrier in obtaining wide crosses. Peng and Qian (1989) observed that the triploid F_1 pollen grains from the cross between *G. hirsutum* x *G. raimondii* were not germinated on the stigma or showed partial germination and abnormal growth. Slow pollen tube growth is one of the major crossability barriers restricting fertilization in wide crosses of cotton. Govilla (1970) found that pollen tube of *G. arboretum* pollen fails to reach ovules of *G. raimondii*, which has longer style than *G. arboretum.* Baloch *et al.,* (2000) observed that difference in style length of tetraploid and diploid species was significant, with tetraploid species having two times longer style than that of diploid species. So, they predicted that differential reproductive structures could at least be partially responsible for crossing failure and reciprocal crosses may be tried for successful fertilization. Study by Saravanan *et al.,* (2010) also supports the work of Baloch *et al.,* (2000) as they reported severe reduction in number of pollen tubes as they grew in style depending on initial pollen load. Apart from arrest of the pollen tube at different levels, several abnormalities like twisting and bulging of the pollen tube, knot formation in pollen tube, lateral enlargement of pollen tube and growth of pollen tube in opposite direction were noticed. Sometimes contents of the pollen tube are not released in the ovule**.** Shakhmedova (1981) reported that pollen tube did not enter the ovules in the cross of *G. hirsutum* x *G. anomalum.*

Post fertilization barriers hinder or retard the development of the zygote after fertilization and normal development of the seed. They include reproductive abnormalities in F_1 hybrids and their later generation progenies. Hybrid inviabilty or weakness may be due to several mechanisms affecting the development of the zygote from the first cell division after fertilization and up to the final differentiation of reproductive organs and formation of gametes. Weaver (1957, 1958) carried out embryological studies in *G. hirsutum* x *G. arboreum* direct as well as reciprocal crosses. Weaver attributed incompatibility in direct cross to physiological imbalance between hybrid embryo and hybrid endosperm. This imbalance caused cessation of embryo development 6 days after pollination (DAP) leading to embryo starvation. In reciprocal crosses, many of nuclei start abnormal divisions giving rise to structural abnormalities like dumb-bell shaped nuclei, large vacuoles and clumping of nuclei.

As a result of wide hybridization, there are two different types of genomes present in a nucleus, due to this, hybrid sterility may arise because of differences in structure and number of chromosomes, lack of chromosome homology resulting in variable number of univalents and production of unbalanced gametes. When we cross tetraploid species with diploid species of *Gossypium* triploid F_1 so form is expected to be sterile because of production of unbalanced gametes. This is common in case of crosses between new and old world cottons *G. hirsutum* x *G. arboreum.* (Gill and Bajaj 1987; Mehetre *et al.,* 2007; Nazeer *et al.,* 2014b), *G. arboreum* x *G. anomalum* (Mehetre *et al.,* 2004b), *G. hirsutum* x *G. raimondii* (Saravanan *et al.,* 2007) etc. Hybrid breakdown is a type of reproductive failure defined as inviability or sterility observed only in the F_2 or later generations of interspecific crosses, while F_1 hybrids are viable and fully fertile. Even if hybrid have been produced successfully and are found to fertile, hybrid breakdown is the next problem it may encounter.

Overcoming cross compatibiltiy : Incompatability observed in wide hybridization of crop plants is a major hurdle in introgression of genes from wild to cultivated species. Boll setting in interspecific crosses of *Gossypium* is limited by physiological boll drop and boll shedding due to injury to pistil during emasculation and pollination. There are reports of increase in boll retention after application of growth regulators. Gill and Bajaj (1987) used mixture of 50 ppm GA_3 + 100 ppm NAA for increasing boll retention in *G. hirsutum* x *G. arboreum* and reciprocal crosses. They applied mixture of growth regulators at base of pedicle for three consecutive days starting from one day after pollination. They reported that boll retention varied between 52.9 - 79 per cent in *G. hirsutum* x *G. arboreum* and 43.7- 60.7 per cent in *G. arboreum* x *G. hirsutum* after application of growth regulator as compared to 6.4- 17.6 per cent retention in the control, where no growth regulator has been applied.

Altmann (1988) observed that cotyledons appeared more fully developed when NOA/GA and NAA/GA treatment were used. Further, reduction in boll absicission with 50 ppm GA_3 + 100 ppm NAA was recorded along with increase in mean boll weight. Also, hormonal treatment resulted in more embryos per boll and improvement of embryo quality. He concluded that application of optimum levels of growth regulators was superior to embryo/ovule culture in obtaining interspecific hybrids in most of the crosses performed during this investigation.

In an another investigation, efforts were made by Mehetre *et al.,* (2002b) to induce boll setting in interspecific hybrids in which boll and seed setting was a problem, so as to use the ovules from these bolls to supplement *in-ovulo* embryo culture. Hence to exploit these hybrids for the introgression of desirable genes from wild to cultivated cotton 16 different treatments, i.e. combination of (i) without sugar and agar, (ii) sugar 30 per cent, (iii) sugar 30 per cent and agar 0.04 per cent with (a) GA_3 50 ppm + NAA 40 ppm, (b) GA_3 50 ppm + NAA 100 ppm, (c) NAA 100 ppm and (d) IAA 100 ppm were used. Out of all tried treatment containing mixed pollen in 30 per cent sugar + GA_3 50 ppm + NAA 100 ppm was found to be effective in inducing boll setting on interspecific hybrids. Also it was observed that different treatments gave different results on different genetic background.

Usefulness of growth regulators in improving crossed boll retention was investigated by Pathak *et al.,* (2003) in intra-*hirsutum* crosses. In general, they observed increased retention of crossed bolls after application of 50 ppm GA_3 + 100 ppm NAA. Only one *G. hirsutum* genotype May Acala gave an overall negative response to hormonal treatment. So, it was suggested that response of genotypes to growth regulators depends on endogeneous hormonal levels. Similar study was conducted in inter varietal crosses of *G. arboreum* (Pathak *et al.,* 2008), where significant differences between mean value of boll retention of direct (15.12%) and reciprocal (24.99 %) crosses was observed.

Rauf *et al.,* (2006) crossed *G. hirsutum* and colchicoid *G. arboreum* in both direct and reciprocal manner. Direct crosses proved successful but reciprocal crosses were complete failure so they tested different treatments of hormonal application for inducing boll setting in reciprocal crosses. They observed highest number of interspecific bolls or seeds per boll when 0.5 mg/l GA_3 and 0.5 mg/l IAA was used in *G. arboreum* genotype FDH-228 and HK-113 respectively. They also reported genotypic specificity to different hormonal treatments. Growth regulators have been successfully used to develop interspecific hybrids in other crops as well *e.g.,* chickpea (Verma *et al.,* 1990), pigeonpea (Sidhu *et al.,* 2000), soybean (Singh *et al.,* 1990) etc.

Even though there are reports of development of interspecific hybrids in cotton through conventional breeding approaches but success is limited due to various barriers, so tissue culture techniques offers an alternative for obtaining interspecific hybrids. One biotechnological technique for overcoming the post fertilization barriers is embryo culture. The first report on successful *in vitro* embryo culture was by Hanning (1904) who grew nearly mature embryos of *Raphanus* and *Cochleria* on mineral salts medium with sugars, amino acids and plant extracts. Laibach (1925) was first to successfully culture hybrid embryos from interspecific crosses of genus *Linum* which normally resulted in aborted seeds.

The first use of embryo culture in cotton was reported by Skovsted (1935). A weak embryo of *G. davidsonii* x *G. sturtianum* was rescued and cultured on sterile glucose-agar media. Beasley (1940) cultured interspecific *Gossypium* species hybrids on White's media. Some of them germinated and formed roots and hypocotyls but did not develop further. He also performed embryological studies to determine the cause of incompatibility and observed that degeneration of endosperm lead to embryo starvation in both *G. hirsutum* x *G. arboreum* and reciprocal cross. Lofland (1950), Dure and Jensen (1957) were successful in obtaining seedlings when embryo was excised 20-25 days post anthesis. However, younger embryos failed to mature *in vitro*.

In vitro culturing of *G. hirsutum* embryos from heart stage to maturity by adjusting osmotic potential of media and using high salt media was reported by Mauney (1961). In a later study, Mauney *et al.,* (1967) performed chromatographic analysis of liquid endosperm from 12-14 day old cotton ovules and found that malic acid (7 mg/ml) was major organic acid and further reported that addition of calcium or ammonium malate (upto 4 mg/ml) to media improved growth and viability of cotton embryos cultured at heart stage. Malate was also observed to effect osmotic pressure of medium. So, embryo could be cultured for longer period of time on low osmotic pressure medium. This eliminated the need for addition of NaCl to maintain osmotic pressure at 10 atm as suggested by Mauney (1961).

After this, the focus of researchers shifted to *in ovulo* embryo culture as it proved to be more simpler and successful method for rescuing embryos. Culturing of ovules is advantageous because these can be easily excised at zygote stage and also provides a "maternal environment" to growing embryo.

Joshi (1960) first reported ovule culture in *Gossypium*. Six DAP ovules were excised and cultured on low salt medium containing casein hydrolysate, vitamins, indoleacetic acid (IAA) and gibberellic acid (GA). Growth of ovules was abnormal and fibres did not grow. This culture method was later modified and ovule growth response was documented by Joshi and Johri (1972). They studied the effect of IAA, KN, GA_3, CH and YE on *in vitro* growth of selfed cotton ovules excised 6 DAP. They observed embryo growth upto early dicotyledonous stage on White's medium containing higher concentration (1000-2000 ppm) of CH, while on lower concentration (upto 250 ppm), embryo grew only upto globular stage. Also, higher concentration of IAA (1-2.5 ppm) did not favour embryo development. Fully differentiated embryos were obtained 96 days after fetilization from 12-celled pro-embryo.

The first successful method of ovule culture for fiber development was given by Beasley *et al.,* (1971). The essential features for success were the use of high salt *Bt* media and use of liquid culture instead of agar solidified medium. However, this report was only concerned with development of ovules and fibres for two weeks and no embryos developed to maturity. Beasley and Ting (1973) studied effect of phyto-hormones (BTP medium) on fiber development in fertilized and unfertilized ovules. They reported that fertilized ovules (2DAP) did not require hormones and exogeneous IAA did not promote additional fibre growth. Addition of exogeneous GA_3, however, had stimulatory effect, while, kinetin and abscisic acid (ABA) were observed to be inhibitory. In case of unfertilized ovules IAA and GA_3 had additive affect for fibre growth. Exogeneous kinetin promoted increase in ovule size but did not support fibre development. They further stated that disposition of parent plant greatly affected the capacity of ovules to grow *in vitro* and also their response to applied growth substances. At the same time, a Belgium group (DeLange and Eid 1971, Eid *et al.,* 1973) published report concerning fibre growth on cultured ovules and found that MS was superior to media with lower salt formulations. They concluded that relatively high nitrogen content of MS was advantageous. They examined the effect of auxin and GA_3 and reached same conclusion as Beasley and Ting (1973).

Stewart and Hsu (1977) found that BTP medium (*Bt* medium with phytohormones) was basically correct for *in ovulo* embryo growth except for poor development of cotyledons. They noted that supplementation of BTP medium with 10-15 mM ammonium ions supported ovule growth and germination of embryos. Further, they observed that after germination, radical tip became necrotic and no lateral roots were formed. Subsequent observations indicated that seedlings were unable to tolerate high-salt or high-sugar media and inositol was inhibitory to root development. Low salt media without inositol allowed balanced root and shoot growth with two to three leaves. They also reported differences in germination response with respect to cultivars. In subsequent study, Stewart and Hsu (1978) reported culturing of 2-4 DAP ovules to obtain interspecific hybrids between Asiatic diploid and American tetraploid cottons in all possible combinations. In most cases, the presence of GA and kinetin was deleterious to recovery of hybrid plants. Consequently, they recommended that only auxin be used when culturing ovules of species other than *G. hirsutum*.

In a similar study, Umbeck and Stewart (1985) recovered interspecific hybrids from eight of twelve crosses made using three wild species as maternal parent and four cultivated species of cotton as paternal parent. They applied GA_3 (3.5 mmol/l) to the flower at anthesis and immature embryos were rescued 15 – 25 DAP and cultured on medium of Stewart and Hsu (1977). They observed that success of fertilization and embryo development was strongly influenced by paternal parent used and degree of hybrid embryo development might be a more important factor than age or size at the time of embryo rescue.

Interspecific hybrids between cultivated diploid species and wild diploid species were obtained by Gill and Bajaj (1984) using MS media supplemented with IAA (1.5 mg/l), kinetin (0.5mg/l) and casein hydrolysate (250mg/l). They applied mixture of growth regulators (NAA @ 100mg/l + GA_3@ 50mg/l) at base of pedicel for 5-8 DAP to prevent early boll shedding. Later on, Gill and Bajaj (1987) used same method to obtain hybrids between *G. arboreum* x *G. hirsutum* by culturing 3 days old ovules. Similar work was done by Kalamani (1996). However, Thengane *et al.,* (1986) observed that no single medium was adequate to ensure complete development of fertilized ovules, hence, they performed sequential five step transfer to different media to obtain interspecific hybrid between *G. hirsutum* cv. Laxmi and *G. arboreum* cv. Jyoti. Dhumale *et al.,* (1996) used BT and MS media for obtaining hybrids in three varieties of *G. arboreum* and four varieties of *G. hirsutum* in different combinations and found that response of hybrid embryos to media was genotype oriented. *In ovulo* embryo culture was used to rescue hybrid between amphidiploid (*G. arboreum* x *G. anomalum*) and *G. hirsutum* by Mehetre *et al.,* (2004b) for combining desirable traits of diploids into cultivated tetraploid.

To improve effectiveness of obtaining interspecific hybrids of *Gossypium* species, Sacks (2008) compared nine media modifications based on earlier studies. He observed highest frequency of germination for MS media fortified with Gamborg's B5 vitamins and additional 1.9g/l KNO_3. They also observed that media without phytohormones produced more seedlings than the media in which different combinations of IAA and kinetin were tested. This was contrary to results of Gill and Bajaj (1987) who observed no germination of *G. hirsutum* x *G. arboreum* without growth regulators. However, Sacks pointed out that differential genotypes used in two studies might account for differing results obtained by addition of auxin and kinetin.

Quantification of level of major and minor elements, carbohydrates, ammonium ions, free amino acid and hormones in cotton ovules, nucelli, and ovule fluid was done by Fuller *et al.,* (2009) to develop tissue culture media that normalized development of early stage globular embryos *in vitro*. To further extend this work, Liddiard and Carman (2010) quantified dissolved oxygen tensions, osmotic potentials, and pH at several locations in cotton ovules during embryony and also reported the procedures to normalize early development of embryos *in vitro* by simulating these parameters. Based on these analyses, Fuller and co-workers (2011) devised chemically defined media and unique culture equipments for inducing rapid differentiation, growth, and germination of cotton embryos starting with globular pro-embryo as explants. They recommended GOS1 formulation for culture of cotton pro-embryos with addition of IAA, mannitol, and phytagel. This formulation differed from MS media by containing 8.2-fold more P, 2.4-fold more K, 2.7-fold more Ca, 5.1-fold more S, 8.8-fold more myoinositol, and arabinose, melibiose, malic acid, citric acid, a variety of amino acids, and mannitol (as an osmoticum, "1.10 Mpa), none of which are in MS medium.

Although most of the researchers have reported the successful production of interspecific hybrids and their further generations in *Gossypium* genus using embryo rescue technique, few have reported failure as well (Altman *et al.,* 1987). So, one can use both the techniques- embryo rescue and direct crosses in field, simultaneously.

Research utilizing *Gossypium* germplasm is essential, because this is a complex genus. Although much has been accomplished in the understanding of the genus, much remains to be done This genus comprises species with differing ploidy levels and represents a high degree of variability, from highly improved allotetraploid species to wild diploid species. This variability has only begun to be tapped as a source of beneficial characteristics.

REFERENCES

Abdalla A M, Reddy O U K, El-Zik K M and Pepper A E 2001. Genetic diversity and relationships of diploid and tetraploid cottons revealed using AFLP. *Theor Appl Genet* **102**:222–29.

Ahmad S, Mahmood K, Hanif M, Nazeer W, Malik W, Qayyum A, Hanif K, Mahmood A and Islam N 2011. Introgression of cotton leaf curl virus resistance genes from asiatic cotton (*Gosssypium arboreum*) into upland cotton (*G. hirsutum*). *Genet Mol Res* **10**:2404-14.

Altman D W 1988. Exogenous hormone applications at pollination for in vitro and in vivo production of cotton interspecific hybrids. *Pl Cell Reports* **7**:257- 61.

Altman D W, Stelly D M and Kohel R J 1987. Introgression of the glanded-plant and glandless-seed trait from *Gossypium sturtianum* Willis into cultivated upland cotton using ovule culture. *Crop Sci* **27**:880-84.

Anjum Z I, Hayat K, Chalkin S, Azhar T M, Shehzad U, Ashraf F, Tariq M, Mehmood H T and Azam M 2015. Development of cotton leaf curl virus tolerance varieties through interspecific hybridization. *Africen J Agric Res* **10**:1612-18.

Arpat A B, Waugh M, Sullivan J P, Gonzales M, Frisch D, Main D O, Wood T, Lesile A, Wing R A and Wilkins T A 2004. *Plant Mol Biol* **54**: 911-29.

Ahton l, Lacape J M, Baudoin J P and Mergeai G 2003. Introduction of Australian cotton genetic variatin into Upland cotton. *Crop Sci.* **43**: 1999 -05.

Beasley J O 1940. The origin of American tetraploid *Gossypium* species. *Am Nat.* **74**: 285 – 86.

Baloch M J, Lakho A R, Bhutto H and Arain M H 2000. Differences in style length and *in vitro* germinated pollen tube length and other reproductive structures of tetraploid and diploid cottons. *Pak J Biol Sci* **3**:1372-74.

Beasley J O 1940. Hybridization of american 26-chromosome and asiatic 13-chromosome species of *Gossypium*. *J Agric Res* **60**:175–81.

Beasley C A, Ting I P and Feigen L A 1971. Test tube cotton. *California Agric* **25**:6-8.

Beasley C A and Ting I P 1973. The effects of plant growth substances on *in vitro* fibre development from fertilized cotton ovules. *Am J Bot* **60**:130–39.

Brubaker C L, Koontz J A, Wendel J F 1993. Bidirectional cytoplasmic and nuclear introgression in the New World cottons, *Gossypium barbadense* and *G. hirsutum* (Malvaceae). *Am J Bot* **80**:1203–08.

Brubaker, C. L. and Wendel J. F. 1994. Re evaluating the origin of domesticated cotton (*Gossypium hirsutum*; Malvaceae) using nuclear restriction fragment length polymorphisms (RFLPs). *Am J Bot* **81**:1309–26.

Deshpande, L. A. and Baig, K. S. 2001. Interspecific Hybridization for Introgression of Fibre Quality and Productivity from Cultivated Tetraploid *G. hirsutum* into Diploid *G. arboreum.* In National seminar on *"Sustainable cotton Production to meet the requirement of industry"* held on 3-4, october2001 at Mumbai. Pp 22 – 27.

Deshpande, L. A., Kokate, R. M., Kulkarni, U. G. and Nerkar, 1992. Cytomorphological studies in induced tetraploid *G. arboreum* and new interspecific hybrid between 4n *G. arboreum* x *G. hirsutum* L. In Proc. of the "1st Vasant Rao Memorial National Seminar on *"Agricultural Sciences–Cotton Development"* held at Nagpur.

Douglas, C. R. and Brown, M. S. 1971. A study of the triploid and 3x-I aneuploid plants in the genus *Gossypium. Am J Botany* **58**: 65-71.

Dhumale, D. B., Ingole G. L. and Durge D. V. 1996. Interspecific hybridization through embryo culture in cotton, *Gossypium arboreum* and *G. hirsutum. Indian J Exp Biol* **34**:288-89.

Dure, L. S. and Jensen, W. A. 1957. The influence of gibberellic acid and indoleacetic acid on cotton embryos cultured *in vitro*. *Bot Gaz* **117** : 254–61.

Eid, A. A. H., Delange, E. and Waterkeyn, L. 1973. *In vitro* culture of fertilized cotton ovules. I. The growth of cotton embryos. *Cellule* **69**:361-71.

Fang D D, Hinze L L, Percy R G, Li P, Deng D, and Thyseen G 2013. A microsatellite-based genome-wide analysis of genetic diversity and linkage disequilibrium in Upland cotton (*Gossypium hirsutum* L.) cultivars from major cotton-growing countries. *Euphytica* **191**:391-401.

Fuller R J, Carman J G and Hess J R 2009. Nutrient and hormone levels in cotton ovules during embryony. *Pl Cell Tissue Organ Cult* **99**:183–92.

Fuller R J, Liddiard V M, Hess J R and Carman J G 2011. Improving cotton embryo culture by simulating *in ovulo* nutrient and hormone levels. *In Vitro Cell Dev Biol Pl* **47**:410–19.

Fulton T M, Grandillo S and others 2002. Advanced backcross QTL analysis of a *Lycopersicon esculentum* x *L. parviflorum* cross. *Theor Appl Genet* **100**: 1025 – 42.

Gill M S and Bajaj Y P S 1984. Interspecific hybridization in the genus *Gossypium* through embryo culture. *Euphytica* **33**:305–11.

Gill M S and Bajaj Y P S 1987. Hybridization between diploid (*Gossypium arboreum*) and tetraploid (*Gossypium hirsutum*) cotton through ovule culture. *Euphytica* **36**:625–30.

Gotmare V P and others 2004. Wild species of cotton and their utilization in India. In Proc. ICGI Workshop held from October 10–13,2004 at Hyderabad.

Govilla O P 1970. Fertilization and seed development in crosses between *G. arboreum* and *G. raimomdii. Indian J Genet* **30**:152-56.

Grover C E, Grupp K K, Jareczek J J, Gallagher J P, Szadkowski E, Seijo J G and Wendel J F 2015. Molecular confirmation of species status for the allopolyploid cotton species, *Gossypium ekmanianum* Wittmack. *Genet Resour Crop Evol* **62**:103–14.

Hanning E 1904. Zur Physiologie pflanzlicher Embryonen. I. Über die Kultur von Cruciferen-embryonen ausserhalb des Embryosacks. *Bot Ztg* **62**:45–80 (Original not seen. Cited by Mehetre S S and Aher A R, 2004. *Indian J Biotechnol* **3**:29-36.

Hutchinson J B 1959. The application of genetics of cotton improvement, Cambridge University Press, London.

Iqbal M J, Aziz N, Saeed N A, Zafar Y and Malik K A 1997. Genetic diversity evaluation of some elite cotton varieties by RAPD analysis. *Theor Appl Genet* **95**:139–44.

Iqbal M J, Reddy O U K, El-Zik K M and Pepper A E 2001. A genetic bottleneck in the evolution under domestication of Upland cotton *Gossypium hirsutum* L. examined using DNA Fingerprinting. *Theor Appl Genet* **103**:547–54.

Joshi P C 1960. *In vitro* growth of cotton ovules. In: *Proc Symp Pl Embryol* pp 199-204. Council of Scientific and Industrial Research, New Delhi.

Joshi P C and Johri B M 1972. *In vitro* growth of ovules of *Gossypium hirsutum. Phytomorph* **22**:195-209.

Kalamani A 1996. Embryo rescue in interspecific hybrids of cotton. *Madras Agric J* **83**:316-17.

Katagery I S and others 2004. transfer of fibre length, strength and fineness from tetraploid to diploids in *Gosypium* species. In Proc. ICGI Workshop held from October 10 – 13, 2004 at Hyderbad, India.

Katarki B H 1971. Varalaxmi, a high yielding hybrid cotton of quality. *Indian Farming* **22**: 35 – 36.

Kulkarni V N and Khadi B M 1998. Long linted *G. arboreum* for meeting textile industrial needs. Paper presented at WCRC-2 held at Athens, Greece. Pp. 363.

Kulkarni V N, Khadi B M and Sangam V S 2001. Conventional and biotechnological approaches for fibre quality improvement. In National seminar on *"Sustainable cotton Production to meet the requirement of industry"* held on 3-4, October 2001 at Mumbai. Pp 245 – 52.

Lacape J M, Dessauw D, Rajab M, Noyer J L and Hau B 2007. Microsatellite diversity in tetraploid *Gossypium* germplasm: assembling a highly informative genotyping set of cotton SSRs. *Mol Breeding* **19**:45–58.

Laibach F 1925. Das Taubwerden von Bastardsamen und die künstliche Aufzucht früh absterbender Bastardembryonen. *Z Bot* **17**:417–59 (Original not seen. Cited by Mehetre S S and Aher A R, 2004. *Indian J Biotechnol* **3**:29-36).

Liddiard V M and Carman J G 2010. Simulating *in ovulo* osmotic potentials and O_2 tensions normalize growth and pigmentation of immature cotton embryos. *Pl Cell Tissue Organ Cult* **102**:1–8.

Lofland H B 1950. *In vitro* culture of cotton embryos. *Bot Gaz* **111**:307–11.

Linos A A, Bebeli P J and Kaltsikes P J 2002. Cultivar identification in Upland cotton using RAPD markers. *Aust J Agric Res* **53**:637–42.

Liu Q, Chen Y, Chen Y, Waang W, Chen J, Zhang T and Zhou B 2015. A new synthetic allotetraploid ($A_1A_1G_1G_1$) between

Gossypium herbaceum and *Gossypium australe*: bridging for simultaneously transferring favourable genes from these two diploid species into upland cotton. *PLOS ONE* doi: 10.1371/journal.pone.0123209.

Mauney J R 1961. The culture *in vitro* of immature cotton embryos. *Bot Gaz* **122**:205–09.

Mauney J R, Chappel J and Ward B J 1967. Effects of malic acid salts on growth of young cotton embryos *in vitro*. *Bot Gaz* **128**:198– 200.

Mehetre S S, Gawande V L and Aher A R 2002a. Incompatibility in wide hybridization of *Gossypium* species: Causes and remedies. *J Cott Res Dev* **16**:111-24.

Mehetre S S, Gawande V L and Aher A R 2002b. Use of exogenous chemicals for overcoming cross incompatability in *Gossypium* species. *J Pl Biol* **29**:33-38.

Mehetre S S, Gomes M and Eapen S 2004a. RAPD analysis of hybrid nature of the offspring of *Gossypium hirsutum* x *G. raimondii*. *Curr Sci* **87**:25-28.

Mehetre S S, Pardeshi S , Pawar S, Gahukar S and Chavan U 2007. *In ovulo* embryo cultured between *Gossypium hirsutum* and *Gossypium arboretum*: hybridity confirmation. *J Cott Res Dev* **21**:131-39.

Mehetre S S, Patil J M and Kharbade S B 2009. Introgression of pink bollworm resistance from wild *Gossypium thurberi* Tod. to cultivated *Gossypium arboreum* L. cotton: pre-breeding efforts. *Curr Sci* **97**:558-64.

Mehetre S S 2010. Wild *Gossypium anomalum*: a unique source of fibre fineness and strength. *Current Sci.* **99**: 58 – 71.

MEYER V G 1974. Interspecific cotton breeding. *Economic Botany* **28**: 56 – 60.

Nazeer W, Ahmad S, Mahmood K, Tipu A L, Mahmood A and Zhou B 2014a. Introgression of genes for cotton leaf curl virus resistance and increased fibre strength from *Gossypium stocksii* into upland cotton (*G. hirsutum*). *Genet Mol Res* **13**:1133-43.

Nazeer W, Tipu A L, Ahmad S, Mahmood K, Mahmood A and Zhou B 2014b. Evaluation of cotton leaf curl virus resistance in BC_1, BC_2, and BC_3 progenies from an interspecific cross between *Gossypium arboreum* and *Gossypium hirsutum*. *PLOS ONE* doi: 10.1371/journal.pone.0111861.

NIU Y Z., Zhang Y G, Guo, B D and HUA S L 1998. Research on creating new germplasm lines through interspecific hybridization in *Gossypium*. *China Cottons* **25**: 16 – 17.

Patel J N and Desai K B 1963. Improvement of Surti cotton through hybridization with Iranian *herbaceum*. *Indian Cotton Growing Review* **17**: 186.

Pathak D, Rathore P and Garg H R 2003. Reciprocal differences and differential response of genotypes to growth regulator application for crossed boll retention in Upland cotton. *J Pl Sci Res* **19**:102-03.

Pathak D, Singh G and Gill M S 2008. Maternal effects and response to growth regulator application for crossed boll retention in intraspecific crosses of *Gossypium arboreum* L. *Crop improv* **35**:28-30.

Peng Y J and S Y Qian 1989. Embryological studies in interspecific hybrids of *G. hirsutum* L x *G. raimondii. Ulbr Acta Agronomica Sinica* **15**:243-49

Percival E and Kohel R J 1990. Distribution collection and evaluation of Gossypium. *Advances in Agron* **44**: 225 – 228.

Phillips L L 1974. Cotton (*Gossypium*). In Handbook of Genetics, Plenum Press, N. Y. and London, 12: 111 – 133.

Pushpam R and Raveendran T S 2006. Production of interspecific hybrids between *Gossypium hirsutum* and jassid resistant wild species *G. raimondii* and *G. armourianum. Cytologia* **71**:407-18.

Ramachandran C K, Krishnamurthy J and Peter S D 1964. Recent advances in interspecific hybridization work involving wild species of cotton in Madras. *Indian Cotton Growing Rev* **18**: 248 – 257.

Rauf S, Munir H, Abdullojon E and Basra S M 2006. Role of colchicine and plant growth regulators to overcome interspecific incompatibility. *Gen Appl Pl Physiol* **32**:223-32.

Sacks E J and Robinson A F 2009. Introgression of resistance to reniform nematode (*Rotylenchulus reniformis*) into upland cotton (*Gossypium hirsutum* L.) from *Gossypium arboreum* L. and a *Gossypium hirsutum* L. / *Gossypium aridium* L. bridging line. *Field Crop Res* **112**:1-6.

Sacks E J 2008. Ovule rescue efficiency of *Gossypium hirsutum* x *G. arboreum* progeny from field-grown fruit is affected by media composition and antimicrobial compounds. *Pl Cell Tissue Organ Cult* **93**:15–20.

Saha S Wu J, Jenkins J N, McCarty J C Jr, Gutierrez O A, Stelly DM, Percy R G and Raska D A 2004. Effect of chromosome substitutions from *Gossypium barbadense* L. 3-79 into *G. hirsutum* L. TM-1 on agronomic and fibre traits. *J Cotton Sci* **8**: 162 – 69.

Saravanan N A, Ram S G, Thiruvengadam G, Ravikesavan R and Raveendran T S 2007. Production and fertility restoration of an interspecific hybrid between *Gossypium hirsutum* L. and *G. raimondii* U. *Cytologia* **72**:195-203.

Saravanan S, Koodalingam K and Raveendran T S 2010. Reproductive abnormalities in interspecific crosses involving *Gossypium hirsutum* and *Gossypium arboreum. Electronic J Pl Breeding* **1**:806-12.

Shakhmedova G S 1981. Comparative study of cotton hybrids and hexaploids. *Referativni Zhurnal* **65**:50.

Sidhu P S, Singh J and Verma M M 2000. Factors affecting successful wide crossing in Pigeonpea. *J Res Punjab agricul univ* **37**:155-60.

Singh R J, Kollipara K P and Hyomitz T 1990. Backcross-Derived Progeny from Soybean and *Glycine tomentella* Hayata Intersubgeneric Hybrids**.** *Crop Sci* **30**:871-74**.**

Skovsted A 1935. Cytological studies in cotton. III. A hybrid between *Gossypium davidsonii* Kell. and *G. sturtainum* F. Muell. *J Genet* **30**:397-405.

Soregaon C D 2004. Studies on genetic introgression in interspecific crosses of cotton. *M. Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

Stalker H T 1980. Utilization of wild species for crop improvement. *Adv Agron* **33**: 111 – 47.

Stewart J Mcd and Hsu C L 1977. *In-ovulo* embryo culture and seedling development of cotton (*Gossypium hirsutum* L.). *Planta* **137**:113–17.

Stewart J Mcd and Hsu C L 1978. Hybridization of diploid and tetraploid cottons through *in-ovulo* embroyo culture. *J Hered* **69**:404–08.

Thengane S, Paranjpe S V, Khuspe S S and Mascarentas AF 1986. Hybridization of *Gossypium* species through *in ovulo* embryo culture. *Pl Cell Tissue Organ Cult* **6**:209-19.

Umbeck P F and Stewart J Mcd 1985. Substitution of cotton cytoplasm from wild diploid species for cotton germplasm improvement. *Crop Sci* **25**:1015-19.

Verma M M, Sandhu J S, Brar H S and Brar J S 1990. Crossability studies in different Cicer species. *Crop Improv* **17**:179-81.

Vroh B, Baudoin J P, Hau B and Mergeai G 1999. Development of high gossypol cotton plants with low gossypol seeds using tri species bridge crosses with in vitro culture of seed embryos. *Euphytica* **106**: 243 – 51.

Wendel J F, Brubaker C L and Percival A E 1992. Genetic diversity in *Gossypium hirsutum* and the origin of Upland cotton. *Am J Bot* **79**:1291–310.

Wendel J F and Grover C E 2015. Taxonomy and evolution of the cotton genus, *Gossypium.* In: Fang D D and Percy R G (ed) *Cotton.* ASA, CSSA and SSSA. 5585 Guilford Road, Madison USA, Agronomy Monograph 57.

Weaver J B 1957. Embryological studies following interspecific crosses in *Gossypium* I. *G. hirsutum* x *G. arboreum. Am J Bot* **44**:209-14.

Weaver J B 1958. Embryological studies following interspecffic crosses in *Gossypium* II. *G. arboreum* × *G. hirsutum. Am J Bot* **45**:10-16.

Zhang X, Zhai C, He L, Guo Q, Zhang X, Xu P, Su H, Gong Y, Ni W and Shen X 2014. Morphological, cytological and molecular analyses of a synthetic hexaploid derived from an interspecific hybrid between *Gossypium hirsutum* and *Gossypium anomalum. Crop J* **2**:272-77.

9

Inheritance of resistance against cotton leaf curl virus disease in *Gossypium hirsutum L.*

R.S.SANGWAN, S. S. SIWACH, ANURADHA GODARA AND S. NIMBAL

DepartmentofGeneticsandPlantBreeding,CCSHaryanaAgriculturalUniversity,Hisar-125004

E-mail : rssangwan@hau.ernet.in

Cotton is the most important cash crop of North India. *G. hirsutum* and *G. arboreum* species are commercially cultivated in this zone. During the year 2013, 2014 and 2015 Upland cotton suffers losses even up to 100 per cent in some areas mainly due to high incidence of cotton leaf curl virus disease (CLCuD) and white fly. This disease is caused by *Gemini* virus which is of considerable concern and is transmitted by whitefly. Cotton leaf curl virus disease is initially characterized by small vein thickening symptoms on young upper leaves of plants. Use of chemicals in controlling the whitefly is costly and not so effective. Moreover, it may be hazardous to men and environment. Therefore, development of a resistant variety /hybrid to this disease is the most effective, long term, less expensive and safe method. First step in this direction is screening and identification of resistant sources and their incorporation in the agronomical superior genotypes/varieties. For his purpose the study of inheritance of character in question is very essential. Inheritance of resistant genes for disease is still under discussion whether it is nuclear or extra-nuclear. Azhar *et al.*, (2010) reported that the resistance dependent on major genes (dominant genes) may lose quickly because of evolution of pathogen for these genes. An alternative approach is needed for partial resistance that depends on the recombination of minor genes. In the present screening and identification of resistant parents from germplasm and breeding material were identified. Crosses were attempted between resistant and susceptible parents to CLCuD. Six generations were developed for study of CLCuD inheritance.

In North India it is the most important cash crop of *kharif* season where only *G. hirsutum* and *G. arboreum* species are grown. About 95 per cent area of cotton is under *G. hirsutum*. Since last two decades cotton crop is very adversely affected by increasing incidence of cotton leaf curl virus disease. It was reported first in Nigeria (1912) on *Gossypium peruvianum* and *Gossypium vitifolia*, Sudan (1924), Tanzania (1926), Philippine (1959), Pakistan (1967) in Multan district on scattered *hirsutum* plants (Hussain and Ali, 1975). It was not well thought-out as a serious disease up to 1987 in Pakistan but appeared in epidemic form in 1992-1993 and it resulted in huge financial losses with the estimated value of $5 billion (US) from 1992-1997 (Briddon and Markham., 2001). It is very complicated disease and is very difficult to calculate the precise estimates of losses caused by it because the occurrence of CLCuD varies from year to year and also varies from area to area under cotton cultivation. The disease caused by geminivirus and the climatic condition of North India remained favorable during the year 2013, 2014 and 2015 for the growth and spread of whitefly. Cotton leaf curl virus disease is a serious threat to cotton production in this region. In India, cotton leaf curl virus disease was first reported in American cotton (*G. hirsutum*) in

Sriganganagar area of Rajasthan state during 1993 (Ajmera, 1994) and during 1994 it also appeared in Haryana and Punjab (Rishi and Chauhan,1994; Singh *et al.*,1994) states in *hirsutum* cotton.

The disease has appeared in an epidemic form during 1997 in the Rajasthan affecting an area of 0.1 million hectares (Anonymous,1998). Cotton leaf curl virus disease is initially characterized by small vein thickening type symptoms on young upper leaves of plants. These irregular thickenings gradually extend and coalesce to form continuous reticulation of small veins. The disease is further characterized by upward or downward curling of leaves and affected leaves become thick, leathery, brittle and greener than healthy leaves. Later formation of cup shaped or leaf laminar outgrowth called “enation” appear on the underside of the leaf. Some time more than one enation may appear. Use of chemicals in controlling the whitefly (the vector of this virus) is costly and it can’t be controlled completely as single whitefly may infect to number of plants. Moreover, it may be hazardous to men and environment. Extensive uses of pesticides have also caused damage to soil quality and fertility (Dinham, 1993). Therefore, development of a resistant American cotton variety to this disease is the most effective, long term, less expensive and safe method to fight against this disease and to enhance the productivity of cotton. Research efforts to develop resistant varieties/hybrids through conventional/ biotechnological approaches along with cultural and management practices are in progress for effectively controlling this disease. Nature has provided cotton with traits like okra leaf type, gossypol glands and trichomes which confer non-preference to the insect pest infestation. Knowledge of genetic architecture of the trait in question to be improved is very important.

Disease incidence and economic losses : It is difficult to estimate the actual losses as it varies from year to year and cultivar to cultivar. Sometimes, cotton field have been found to show as much as 100 per cent damage and in recent years a recovery from disease incidence have been observed in later stages of maturity. The reduction in yield due to CLCuD incidence depends upon the time of infection and severity of disease. Monga *et al.*, 2004 reported that there was reduction in monopodia, sympodia, leaf size, inter node length and plant height as the disease grade increases. Yield losses due to this disease is reported to be 38 -60 per cent from Haryana, Punjab and Rajasthan. (Malathi *et al.*, 2004). Up to 20 per cent losses have been reported due to this disease in Sudan in *G.barbadense* var. ‘Sahel’. Singh (2006) studied that on an average, there was 50.4 per cent reduction in number of bolls due to CLCuD infection, reduction of 42.9 per cent in the boll weight. Due to CLCuD the fibre length was reduced by 5.2 per cent, strength by 5.4 per cent, elongation by 10.0 per cent, uniformity by 2.2 per cent and micronaire value by 4.1 per cent in the diseased plants over healthy plants. Therefore, on the basis of four years studies they concluded that CLCuD infection adversely affects both seed cotton yield and quality. Similarly Khan *et al.,* (1995) and Akhtar *et al.*, (2009) measured losses inflicted by CLCuD by comparing yield and components (number of bolls / plant and yield / plant).

Selection of parents : Four parents including two resistant (H 1098-i and H 1117) and two susceptible (B 59-1678 and HS 6) to cotton leaf curl disease were chosen as the experimental material for the present study.

These four parents were used to develop four crosses, H 1098-i x B 59-1678 (R x S), H 1117 x HS 6 (R x S), H 1098-i x H1117(R x R) and B 59-1678 x HS 6 (Sx S). These crosses were designated as cross I, cross II, cross III and cross IV, respectively.

Development of basic generations : During *kharif*, 2011, the parents were identified to fulfil the objectives and F1 crosses between these parents, namely H1098-I, H 1117, B 59-1678 and HS 6 were made. The F1 hybrids and parents were raised during *kharif,* 2012. Each F1 was selfed to obtain F2 generation and simultaneously backcrossed to both of its parents to produce backcross generations (BC1and BC2). Fresh crosses were also made to obtain the F1 seed and all the parents were selfed to get their seeds for the next year. Thus, the experimental material finally comprised of six generations, namely P1, P2, F1, F2, BC1 (backcross to first parent P1)and BC2 (backcross to second parent P2).

Layout and design of the experiment : The experimental material comprised of six generations i.e. parents (P1 and P2), F1, F2 and back crosses (B1 and B2) of four crosses was grown in a compact family block design with three replications during *kharif*, 2013 at Cotton Research Area of CCS Haryana Agricultural University, Hisar. There was a single row of non segregating generations (P1, P2 and F1), 20 rows of F2, and 8 rows of each BC1 and BC2 generations. The length of each row was 6 m with spacing of 67.5 x 30 cm. In order to build up heavy inoculum pressure one row of highly susceptible line (HS 6) was planted at the periphery of the experimental area. Normal cultural practices were followed except no insecticidal spray was given for control of white fly (*Bemisia tabaci* Genn) population in the field. White fly is the vector of cotton leaf curl virus disease. Reaction of cotton leaf curl virus disease was recorded on all the plants in all the three replications.

Observation on cotton leaf curl virus disease (CLCuD) : Observation on CLCuD was recorded under field condition in each replication on all the plants of each of the non –segregating generations (P1, P2 and F1), backcross generations and the F2 generation. Disease was scored on 0 -5 grade depending upon the response to the cotton leaf curl virus disease CLCuD. Disease symptoms were recorded every fortnight and final observation was taken on September 15, 2013.

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

0 = Immune, Complete absence of symptoms 0 per cent disease incidence

1 = Highly resistant, Very minute thickening of veins, 0-10 per cent disease incidence

2 = Resistant, Thickening of small group of veins, 10-20 per cent disease incidence

3 = Susceptible, Severe vein thickening and leaf curling developed at the top of the plant, 20-40 per cent disease incidence

4= Moderately susceptible, Severe vein thickening and leaf curling developed on the half of the plant canopy, 40-70 per cent disease incidence

5 = Highly susceptible, Severe vein thickening, leaf curling and full stunting of the plant, 70-100 per cent disease incidence.

Inheritance of resistance to cotton leaf curl disease : Due to very high incidence of CLCuD, complete absence of symptoms i.e. 0 % disease incidence was not observed in both the resistant parents. Although they falls in resistant category. In both the resistant x susceptible crosses (H 1098 – i x B 59 – 1678 and H 1117 x HS 6) all the F_1 plants were resistant on the basis of per cent disease index for CLCuD indicated the complete dominance of resistance over susceptibility. F2 generations segregated nearly 15 resistant and 1 susceptible indicated two genes involvement and their segregation was also near to 3 resistant and 1 susceptible with role of some modifier gene was also not ruled out. Main reason for this confusing obsverations were unavailabilty of immune parents for such study. No complementary gene action was observed in susceptible x suscetible cross as all he plants of this cross were susceptible.

Genetical basis of cotton leaf curl virus disease: In the present study, resistance to CLCuD was dominant over susceptibility. Similar results have been reported by Azhar *et al., (*2010), Bachchan Kumar (2002) and Ali (1997). In F2 generation of these crosses, segregation for resistance gave a good fit to the phenotypic ratio of 15 (resistant): 1 (susceptible), which suggested that presence of either or both dominant genes produces resistance reaction. Backcross generation of resistance x susceptible cross with susceptible parent also segregated in 3 (resistant): 1(susceptible) ratio which further confirms that two recessive genes in homozygous condition were responsible for expression of disease and presence of dominant gene(s) at either locus or at both loci result in resistance. Resistant and susceptible parents used in the present study were diverse for two genes. Expression of resistance in parents H1117 and H 1098 – i having resistance to CLCuD was governed by two dominant genes in homozygous condition, whereas susceptibility to this disease in susceptible parents was governed by two recessive genes in homozygous condition. Ahuja *et al.,* (2007) made crosses among 30 germplasm lines of upland cotton. In 22 crosses, 4 types of segregation patterns were obtained in the F2 generations. A good fit for 15 (resistant):1 (susceptible), 13 (resistant):3 (susceptible), 9 (resistant):7 (susceptible) ratios indicated digenic control of the trait with duplicate dominant, dominant inhibitory, and duplicate recessive epistasis, respectively. Three gene controls with triplicate dominant epistasis was obtained in one of the crosses. Contrary to this, in the earlier reports, Saddig (1968) and Rehman *et al.,* (2005) found that resistance to CLCuD was controlled by a single dominant gene. This might be because of different genetic stock used in their study. To determine whether the genes for resistance to CLCuD in H 1117 and H 1098 – i were same or different, the cross between resistant (H 1117) x resistant (H 1098 – i) was attempted in F2 generation, no segregation was observed indicating that genes for resistance to CLCuD in H1117 and H 1098 – i were same. This was further confirmed by the backcross generations.The possibilities of obtaining resistant reaction by complementary interaction of genes responsible for susceptibility was explored by studying the cross between susceptible x susceptible (B 59 – 1678 x HS 6). All the plants in segregating as well as in non segregating generations of this cross were susceptible. This indicated that there was no complementary interaction between the genes for susceptibility in the susceptible parents used. Whereas the nuclear inheritance is under discussion, the extra chromosomal inheritance is also a secret and considered to be absent by Rehman *et al.,* (2005) but the presence of reciprocal differences in the cross LRA 5166 is advocated by Khan *et al.*, (2007).

Till now nothing can be concluded about

CLCuD behaviour, its appearance, correlation with environmental conditions, its losses etc. During *kharif*, 2015 in a highly susceptible variety (HS 6) to this disease infection appeared in early stage of growth i.e. in first fortnight of J with per disease index grade of more than 3 but this variety recovered tremendously by first week of October will produce a yield between 15 to 20 q/ha but it is not true for different years / location / sowing time of crop or some other factors amy be invloved.

REFERENCES

Ahuja, S.L., Monga, D. and Dhyal, L.S. 2007. Genetics of Resistance to Cotton Leaf Curl disease in *Gossypium hirsutum* L. under Field Conditions. *J. Hered.***98**: 79–83

Ajmera, B.D. 1994. Occurrence of leaf curl virus on American Cotton (*G. hirsutum*) in north Rajasthan.Paper presentation, National Seminar on Cotton Production Challenges in 21st Century, April 18-20 Hisar. India.

Akhtar, K.P., Wasim, M., Ishaq, W., Ahmed, M., Haq, M.A. 2009. Deterioration of cotton fiber characteristics caused by cotton leaf curl disease. *Spanish J. Agri. Res.* **7** : 913-18

Ali, M. 1997. "Breeding of cotton varieties for resistance to cotton leaf curl Virus", *Pak. J. Phytopathol.* **9** : 1-7.

Anonymous 1998. Annual Report of All India Co-ordinated cotton Improvement Project for the year1997-98. Pathology report. Coimbatore, Tamil Nadu-641 003.

Azhar, M.T., Rehman, M.U., Aftab, S., Zafar, Y. and Mansoor, S. 2010. Utilization of natural and genetically-engineered sources in *Gossypium hirsutum* for the development of tolerance against cotton leaf curl disease and fiber characteristics. *Int J Agric Biol* **12**: 744-48.

Bachchan K. 2002. Genetic studies on Cotton leaf Curl Virus Disease and characters of economic importance in cotton (*Gossypium hirsutum* L.). *Ph.D. Thesis.* CCSHAU, Hisar. pp 120.

Dinham, B. 1993. The pesticide hazard, Zed books, London.224pp

Hussain, T. and Ali, M. 1975. A review of cotton diseases in Pakistan. *Pak Cottons* **19**: 71-86

Khan, S.M., Aslam, L. and Bashir, M. 1995. Effects of cotton leaf curl virus disease on yield and yield components of cotton cultivars. In: National conference on plant sociologist by Pak. Bot. Soc. in collaboration with Pakistan Phytopathological society at NARC, Islamabad, March, 28-30

Malathi, V.G., Padmalatha, K.V., Radhakrishnan, G. and Varma, A. 2004. Recent molecular approach for understanding and management of cotton leaf curl virus disease. National symposium on *"Changing World Order Cotton Research, Development and Policy in Context"* held at ANGRAU, Hyderabad. Aug. 10-12

Mather, K. and Jinks, J. L. 1982. *Biometrical Genetics*. University Press, Cambridge, U.K., pp. 1-389

Monga, D., Sheo, R. and Mayee, C.D. 2004. Strategies for cotton leaf curl virus disease management. National symposium on *"Changing World Order Cotton Research, Development and Policy in Context"* held at ANGRAU, Hyderabad. Aug. 10-12

Rehman, M., Hussain, D., Malik, T.A. and Zafar, Y. 2005. Genetics of resistance to cotton leaf curl disease in *Gossypium hirsutum* L. *Pl Pathol* **54**: 764-72

Rishi, N. and Chauhan, M.S. 1994. Appearance of leaf curl disease of Cotton in northern India. *J. Cotton Res. Dev.* **8**: 174-80.

Rybicki, E. and Fouquet, C. 1998. Geminiviridae classification: current concepts and demarcation criteria. 2nd Int'l workshop on *Bemisia* and *Gemini* viral Diseases. June 7-12, 1998.

Singh, D. 2006. Effects of symptom grades of cotton leaf curl disease on the yield and quality of fibre of upland cotton in Punjab.*Indian Phytopathology.* **59**: 148- 53.

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Development of GIS and GPS based spatial cotton fibre quality maps

V. G. ARUDE, S. K. SHUKLA, P. G. PATIL AND G. P. OBI REDDY

Central Institute for Research on Cotton Technology,, Mumbai -400 019

E-mail : arudevg@gmail.com

ABSTRACT : A case study was carried out to design and develop Geographical Information System (GIS) and Geographical Positioning System (GPS) based spatial cotton fibre quality maps for Nagpur district of Vidharbha region of Maharashtra. Spatial database and spatial fibre quality maps for parameters such as 2.5 percent span length, uniformity ratio, fineness, strength, elongation, ginning percentage, short fibre content, degree of reflectance and degree of yellowness were developed. Spatial distribution, classification and characterization of the district based on the fibre quality were carried out to provide site specific information. The quality features of the cotton grown in Nagpur district was analyzed by visualizing the spatial maps. The 2.5 per cent span length of the cotton was observed to fall in two classes, long and extralong, and the uniformity ratio into three classes, average, good and excellent. The fineness of the cotton could be categorized into three classes, very fine, fine and average. The strength of the cotton was found between good and very good. It was observed that cotton grown in moderately deep to deep clayey soil are of extralong staple with average fineness, good strength and lower short fibre content. Cottons grown in very shallow to shallow loamy soils were of long staple, and fine with average strength and higher short fibre content. Cotton produced in plains was found to have higher staple, fineness and strength compared to those produced at higher elevations. It is concluded that spatial maps would be highly useful to traders, ginners, researchers and industry for efficient planning and decision making process.

Keywords: Cotton, fibre quality, GIS, GPS, spatial maps

With the global shift towards market economics, the need for timely, reliable and location specific information has become more important. A comprehensive knowledge of the spatial cotton quality parameters is of fundamental importance to cotton traders and industry for efficient planning of their business.Cotton is being traded in the market based on its variety and grade. First hand spatial information related to cotton grown and its quality parameters is not available. Even if available, it is represented in tabular forms and it is difficult to interpret and visualize the variations and assess the availability of particular quality of cotton in the district, region or state.

Recently emerged technologies like Geographic Information System (GIS) and Geographical Positioning System (GPS) are widely used as spatial analysis tool for effective and efficient means of data acquisition, data storage and retrieval, manipulation and analysis and output generation (Baily, 1990). A GIS offers many advantages for spatial data management and presentation, including a structured representation for data, data management functions, and most importantly, visualization of data. Spatial simulations can take advantage of large quantities of data previously digitized as GIS layers. (Mccauley, 1999). It provides continuous surfaces from point data. Spatial distribution, classification and characterization of the region are possible with GIS based on any phenomenon. It helps to analyze trends over time, and spatially evaluate impacts caused by development. GIS allows developing decision making processes much faster (Bantalan *et al.,* 2000)

A GIS combines geographic mapping capabilities with a database management system. A GIS database consists of a set of data layers, usually referencing a common coordinate system, which describe different thematic or quantitative information. Applying GIS to the process of preparing crop estimates has improved accuracy while lowering costs (Fourie, 2008).

GIS based spatial analysis was conducted and the best locations for harvest collection centres were determined, based on the shortest and least cost path of delivery by the farmer. The maps produced have proven to be critical tools for the field officers for route planning when conducting field visits. This has led to a considerable cut in the cost of production (Felix, 2011)

To circumvent this problem, a case study was carried out and to develop GIS and GPS based spatial fibre quality maps for cotton grown in Nagpur. Spatial fibre quality maps would be useful for classification of the area under cotton based on fibre quality. Spatial maps provide site specific information. As visual interpretation of information in the form of maps allows finding variations quickly, these maps would be highly useful to traders, ginners, policy makers and researchers for systematic planning of their interest for the particular area or the region.

MATERIALS AND METHOD

Seed cotton samples from spatial locations were collected by using GPS from the cotton growing area of Nagpur district by following stratified sampling method. In stratified sampling method the population is divided into subpopulations (strata) and random samples are taken of each stratum in a number proportional to the stratum's size when compared to the population. The longitude, the latitude and the elevation of the locations were noted. A GPS instrument- Magellan Triton 200 was used for recoding the spatial locations. The study was carried out during the crop season 2009-2010.A total of 306 samples were collected from Nagpur district. The spatial locations were widely distributed and representative of the study area with predominantly grown cotton varieties. Secondlyspatial locationswere recorded from thesampling area by using GPS (Fig. 1).

The samples were ginned on the Lilliput gin developed by CIRCOT. The ginned samples were tested on High Volume Instrument (HVI 900) for measurement of fibre quality. Digitization and geo-referencing of the toposheets of Nagpur district were carried out. The noncotton growing area was delineated from the cotton growing area.

The spatial database and the spatial fibre quality maps for parameters namely 2.5 percent span length, uniformity ratio, fineness, strength, elongation, ginning percentage, short fibre index

Table 1. Talukawise samples collected from Nagpur district

Sr. No.	Taluka	Spatial locations
1	Parsioni	53
2	HIngna	36
3	Narkhed	49
4	Ramtek	19
5	Katol	41
6	Saoner	48
7	Kalmeshwar	43
8	Kamptee	17

Fig 1. Recording of spatial location by using GPS.

(SFI), degree of reflectance (Rd) and degree of yellowness (+b) were prepared. Spatial distribution, classification and characterization of the Nagpur district based on each fibre quality were carried out. These spatial fibre quality maps were correlated with the soil maps, such as soil depth and soil texture.

RESULTS AND DISCUSSION

GIS based spatial fibre quality database and maps : Fibre quality and GPS data of spatial locations obtained from the sampling area was analyzed and depicted in Table 2.

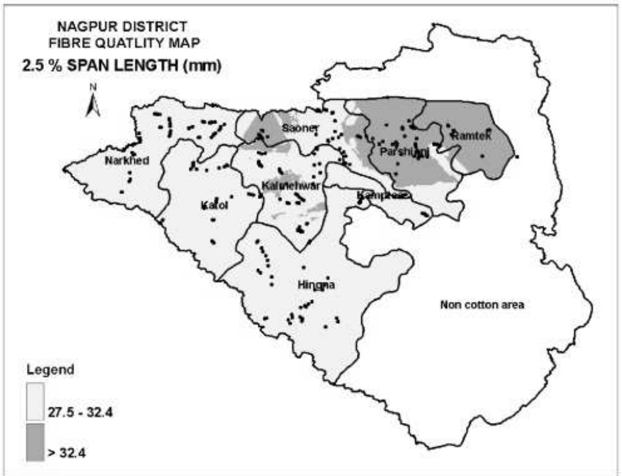
The spatial database and maps for fibre quality parameters was developed using ARCGIS software. Significant variation in fibre quality parameters among the different Talukas were observed in Nagpur district. Spatial database and spatial fibre quality maps were prepared. The spatial maps of Nagpur district for different fibre quality parameters are shown below (Fig. 2a to f).

Spatial distribution, classification and characterization of the Nagpur district based on the fibre quality were carried out. The quality features of the cotton grown in Nagpur district was analyzed by visualizing the spatial maps (Table 3).

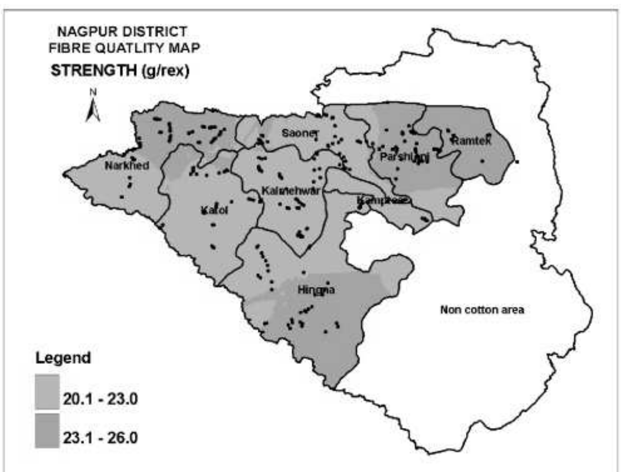
The features of the cotton grown in Nagpur district that was observed by looking at the maps were, staple of the cotton was found to be long and extralong, uniformity ratio was observed to be from average to excellent, fineness between very fine to average and the strength good to very good.

Correlation of spatial fibre quality maps with soil maps : The soil depth, the soil texture and the elevation maps of the Nagpur district were prepared in the GIS environment. The soil depth maps of the cotton growing area were delineated from the noncotton growing area. The soil in thestudy area was found to be clayey and loamy based on the depth of soil (Fig. 3). Further based on the texture, the soil in study area was found to be deep, moderately deep, moderately shallow, shallow, very shallow and extremely shallow (Fig. 4). The elevation of the study area was found between 245 to 470 m.

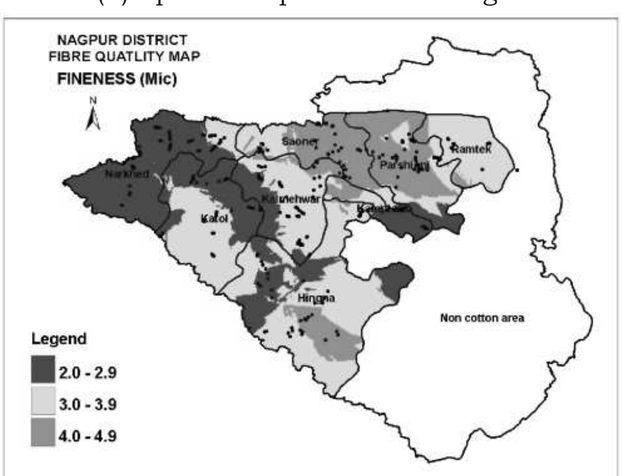
The cotton produced in Nagpur district was found to be of long and extra long staple. 2.5 per cent span length was found between 28.1 to 33.9 mm. Cotton produced in the deep clayey soil was found to be extralong type. In loamy soil, the long staple cotton was mostly grown. At higher elevations, fibre length of the cotton was found to lower compared to the cottons in the plains.
The fineness of cottons produced in this region was found between 2.9 to 4.2 mic. In moderately deep to deep clayey soil, fineness was found to be of average category and ranged between 4.0-4.9 mic. In shallow loamy soils, the fineness was observed in the fine category and ranged between 3.0-3.9 mic. At higher elevations in clayey soil, the fineness of the cotton was found below 3.0 mic. At higher elevations fineness of the cotton was found to be comparatively lower than the



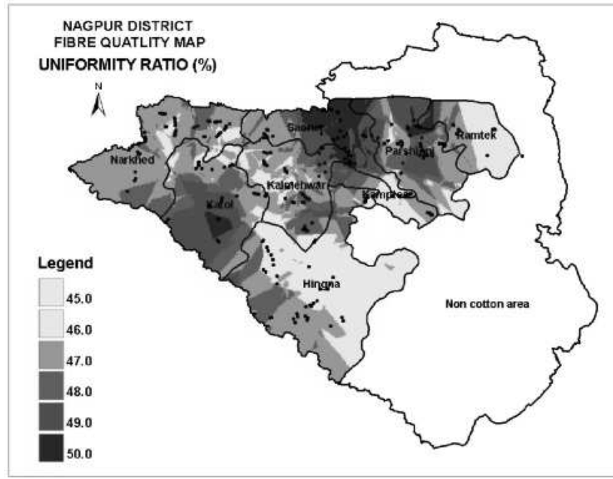
(a) Spatial map for 2.5 percentspan length



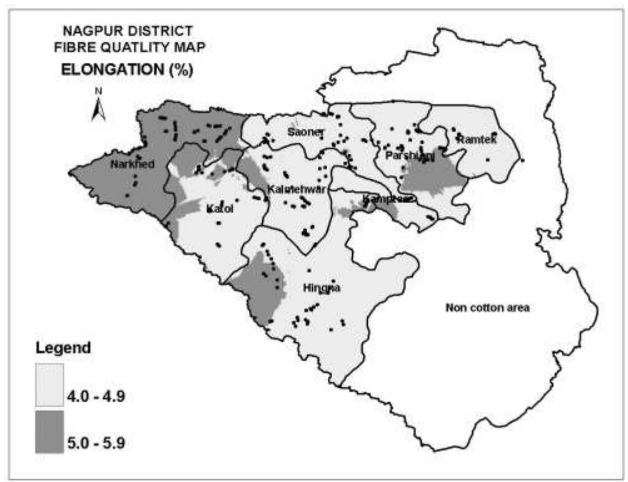
(b) Spatial map for fibre strength



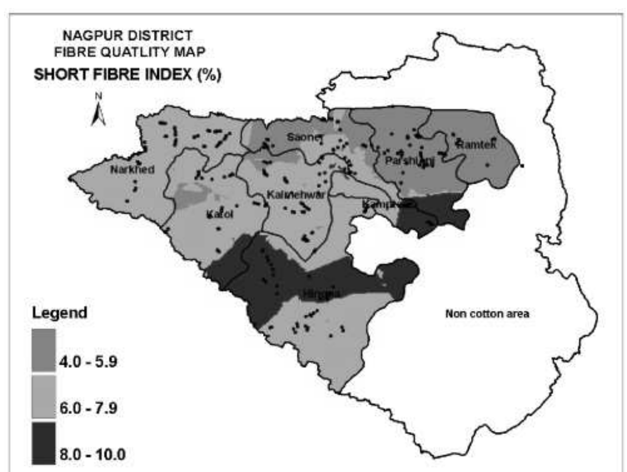
(c) Spatial map for fineness



(d) Spatial map for uniformity ratio



(e) Spatial map for elongation



(f) Spatial map for short fibre content

Fig 2. Spatial fibre quality maps of Nagpur district

Table 2. Variation in the fibre quality parameters in the Nagpur district.

Parameter	Min	Max	Average
Logitude	78.24.17 E	79.23.04 E	—
Lattitude	20.54.33 N	21.50.55 N	—
Location elevation(m)	204	324	318
GP (%)	27.2	40.9	33.1
Fibre length (mm)	24.0	36.4	30.7
Uniformity ratio (%)	39	54	48
Fineness (mic)	2.2	5.6	3.6
Strength (g/tex)	17.7	27.5	23.6
Elongation (%)	3.6	6.4	5.0
SFI (%)I	3.5	14.6	6.1
Rd (%)	54.3	84.8	77.4
+b (%)	4.6	10.8	7.7

Table 3. Fibre quality of cotton as visualized form spatial maps

Fibre quality parameter	Classification	Range
2.5 per cent span length (mm)	Extra long	> 32.5
	Long	27.5-32.5
Uniformity ratio (%)	Excellent	> 47
	Good	45-46
	Average	44-45
Fineness (mic)	Very Fine	< 3.0
	Fine	3.0-3.9
	Average	4.0-4.9
Strength (g/tex)	Very Good	> 26.1
	Good	23.1-26.0

cottons in the plains.

The fibre strength of the cottons produced in this region was found to range from 20.2 to 26.0 g/tex. In moderately deep to deep clayey soil, strength was found to be of good category ranging from 23.1 to 26.0 g/tex. In shallow loamy soils, the strength of the cotton was observed in the average category and ranged from 20.1 to 23.0 g/tex. At higher elevations, strength was found to be a bit lower than the cottons in the plains.

The per cent fibre elongation was found better in clayey soils than loamy soils. In clayey soils, it was found to range from 5.0 to 5.9 per cent and in loamy soils 4.0 to 4.9 per cent. The short fibre content of the cotton produced in this region was found to vary from 4 to 10 per cent. Cottons in loamy soils found to have short fibre content of 6.0 to 7.9 per cent and in clayey soils 4.0 to 5.9 per cent. Cottons produced in clayey soils were found to have lower short fibre content than the cottons in loamy soils.

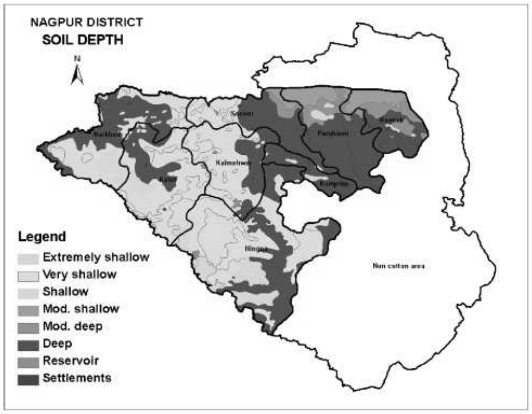


Fig 3. Soil depth map for Nagpur district

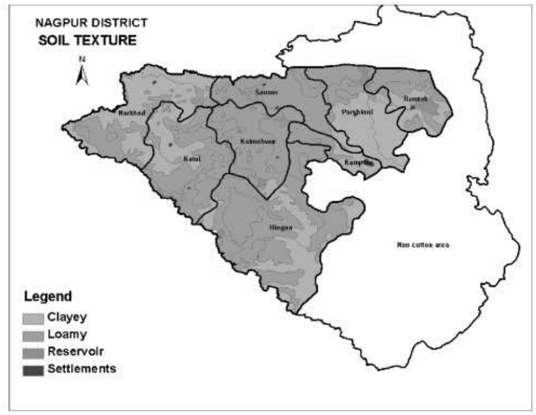


Fig 4. Soil texture map for Nagpur district

Table 4. Cotton fibre quality with respect to soil type

Soil type	Fibre Quality
Moderately deep to deep clayey	Extra-long staple, average fineness, good strength and lower short fibre content.
Very shallow to shallow loamy	Long staple, fineness of fine category, with average strength and comparatively higher short fibre content.

CONCLUSIONS

- The spatial distribution, classification and characterization of the Nagpur district based on the fibre qualitywerefound to be very effective in visualization and interpretation of the data.
- The 2.5 per cent span length of the cotton was observed to fall in two classes *i.e.* long and extralong, uniformity ratio into three classes *i.e.* average, good and excellent, fineness in three classes *i.e.* very fine, fine and average and the strength was found between good and very good.
- Definite trend in fibre quality with soil type was noted.
- Spatial maps found to be useful to traders, ginners, researchers and industry for efficient planning and decision making process as it provides site specific information.

REFERENCES

Bailey, T.C. 1990. GIS, simple system for visual, interactive, spatial analysis.*The Carto Journal.* **27** : 79-83.

Buntalan, F.J., Maji, A.K. and Ahmed, I. 2000. Fundamental aspects of GIS inGIS application in cropping system analysis-case studies in Asia. Proceedings. Cornell University - *ICRISAT, Publication,* pp.7-12.

Felix, N. Mutuaa, Craig Von, Hagenb and David, Kuriac 2011. Cotton mapping in Kenya: GPS-based data collection – A cost comparison with high resolution satellite imagery mapping. *International Transaction Journal Engineering, Management, Applied Sciences Technologies.* **2** : 5-25

Fourie, A. 2008. Better Crop Estimates in South Africa. Integrating GIS with other business, systems.

Mccauley, J.D. 1999. Simulation of Cotton Production for Precision Farming. Kluwer Academic Publishers. pp. 3-4.

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Weed management – Present status and future strategies for cotton crop

P.NALAYINI AND K.SANKARANARAYANAN

Central Institute for Cotton Research, Regional Station, Coimbatore -641003

E-mail : nalayiniganesh@gmail.com

ABSTRACT : Weeds are considered as one of the important biotic constraints in agro ecosystems. In many parts of the world, chemical control of weeds with herbicides is the predominant method of weed management not only in cotton but also in major agronomic crops. Weed management in cotton is achieved through a combination of methods that include cultural, mechanical and chemical approaches. As use of herbicides has increased, more and more cases of resistant weeds have been documented. Since the first reported case of weed resistance in 1970, there are 461 unique cases (species x site of action) of herbicide resistant weeds globally, with 247 species (144 dicots and 103 monocots). Weeds have evolved resistance to 22 of the 25 known herbicide sites of action and to 157 different herbicides (Annonymous, 2015). To preserve the utility of herbicides in agriculture, active resistance management is essential, using methods such as herbicide rotation, mixing herbicides with different mechanisms of action, combining non chemical methods like solarization, mulching with organic and inorganic mulches, stale seed bed technique, mechanical removal, growing compatible intercrops as smothering crops and combination of all the above techniques wherever possible keeping in view of the environmental safety and sustainability of the system. Although, herbicide tolerant genetically modified (HTGM) crops offer broad spectrum weed control encouraging the farmers to adopt reduced – or no-tillage cultivation, eliminating the use of some of the environmentally suspect herbicides, there is concern among weed scientists that over-reliance on fewer weed management strategies will result in evolution of resistance to the useful herbicides and/or population shifts to naturally resistant weed species. Recent advances in nano-biotechnology have potential to be explored in developing nano herbicides which can penetrate and kill the weed seeds preventing them from germinating into harmful weeds. The micro encapsulation technology has good potential for controlled release of active ingredient for the extended period of weed control. As the world is gearing up towards challenges of climate change, the weed scientists should initiate and design weed control strategies to meet the challenges posed by weeds keeping the environmental safety at the foremost concern.

Cotton is sensitive to weed competition due to its slow initial growth and wider spacing gives greater chance to high weed infestation. Also, in recent years, *Bt* Cotton which is high yielding and responsive to higher levels of inputs like fertilizers, irrigation etc.,is grown under intensive cropping system, all these factors promote luxurious growth of weeds which grow more quickly than cotton and compete strongly for soil moisture, nutrients, light and space. The yield reduction due to uncontrolled weed infestation was reported between 50-85 per cent (Joshi, 1997). Worldwide consumption of herbicides represents 47.5 per cent of the 2 million tons of pesticide consumed each year(Sopefia *et al.,* 2009).Indiscriminate use of herbicides leads to resistance development. Over the last 40 years, herbicide resistance has increased worldwide at an exponential rate (Heap,2004),mirroring the previous trends observed with insecticide and fungicide resistance (Holt and LeBaron,1990).In parallel, the rate of discovery of new herbicide modes of action has considerably slowed down (Rasmussen *et al.,* 1999). Management of herbicide resistance is therefore receiving increasing attention to reduce new cases of resistant weed species evolution, in order to prolong the economically useful lives of herbicides. Today, on account of non availability of labour for timely weeding, relatively longer crop duration of cotton crop and enhanced emphasis towards cleaner cotton fibre due to competition from globalization makes weed management as one of the most costly production practices in cotton cultivation and the integration of efficient, economical and environmentally safe weed management system is the need of the hour.

Cotton associated weeds : Weeds of cotton fields vary widely in their floral composition as well as density depending on the ecological situation and crop management. Though about one hundred weed species were reported as associated with cotton, only a dozen of them are responsible for significant yield losses. In India, major weeds associated with cotton crop are *Trianthema portulacastrum,Dactyloctenium aegyptium,Digitaria sanguinalis*,*Ischaneum polosum*,*Alleteropsis crimicina,Eragrostis tenella*, *E.japonica*,*E.major*, *Paspalam disticum*, *Sorghum halepense*, *Brachiaria reptans,Eleusine indica*, *Cyanodan dactylon, Cyperus rotundus*,*Vernonia cinerea*, *Spharamthus indicus*, *Caesulia axillaris*, *Abutilon indica*, *Phyllanthus madraspatensis*, *P.niruri*, *Vicia indica*, *Convolvuilus arvensis*, *Oscimum basilicum*, *Hibiscus malvastrum*, *Lenchus aspewra, Conyza stricta*, *Digera arvensis, Corchorus tridens* and *Enchinochloa colonum*.

Critical period of crop weed competition : The critical period of crop weed competition is the shortest time span in the ontogeny of crop when weeding will result in the highest economic returns. The crop yield obtained by managing weeds during this period should provide crop yields sufficiently close to those obtained by the full season weed control. Balyan *et.al.,* (1983) reported that initial 40 to 60 DAS as critical period of weed competition beyond which keeping the crop free of weeds did not bring any significant improvement in yield. The critical period of weed control was between 20 and 60 DAS as reported by many workers (Shelke and Bhosle, 1989; Saraswat, 1989).The competition of carpet weed (*Trianthema portulacastrum*) was more during initial 50 days after sowing whereas the competition of barnyard grass (*Echinochloa crusgalli*) was more during 50 and 100 days after sowing as inferred by Panwar and Malik (1991) while Douti (1995) specified the critical period of weed competition as 28- 42 DAS for cotton crop. Thus, depending on type of weeds and location, the critical period of weed competition in cotton could be up to 60 days after sowing.

Weed control methods : In India, weed control in cotton has been done traditionally by employing hand labour, animal power or a combination of both. Herbicidal weed control was suggested to be promising. Integrated approach for weed control in cotton reported to be plausible conjecture.

Chemical weed control : Pre emergence herbicides are applied before the crop or weeds have emerged. In annual crops, this is normally done after planting the crop, but before the emergence of weeds. Sprankle (1974) reported that pendimethalin at 0.6 to 1.5 kg/ha incorporated pre sowing gave excellent weed control in cotton. Parshutin *et al.,* (1980) recommended a pre- emergence application of higher dose of pendimethalin upto 2.0 kg/ha for effective control of weeds compared to trifluralin at 2.0 kg/ha and fluometuron 1.2 kg/ha. Chandler (1984) observed that dinitroaniline herbicides controlled most annual grasses and small seeded broadleaved weeds except perennial weed species. Akhtar *et al.,* (1986) obtained effective control of *kharif* weeds especially broadleaved weeds with pendimethalin 1.5 kg/ha. Panwar *et al.,* (1989) reported that pre-emergence application of pendimethalin 1.25 kg/ha gave the best control of *Trianthema portulacastrum* and *Echinocloa crusgalli.*Solaiappan *et al.,* (1992) observed that pre-emergence application of diethyl ether at 1.5 kg/ha controlled the weeds associated with cotton and enhanced the seed cotton yield. Rout and Satapathy (1998) found that pre emergence application of metolachor at 1.25 kg/ha to cotton controlled weeds efficiently and enhanced the seed cotton yield.

Pre emergence herbicides offer weed control only for a limited period and hence late emerging weeds escape from killing and warrants for post-emergence weed control. Manjunath and Panchal (1989) reported efficient weed control with post-emergence application of fluchloralin 1.5 kg/ha and fluazifop butyl 0.5 kg/ha. Staple (pyrithiobac-sodium) is a herbicide which has been applied as an over-the top post-emergence herbicide in cotton. It has to be applied at a minimum rate of 0.04 kg a.i./ha to control weed populations from interfering with the cotton harvest (Warrick,1996). Allen *et al.,* (1997) reported that there was no yield reduction with post-emergence application of pyrithiobac at 105 g/ha. Swann and Wilson (2001) reported that pyrithiobac can be applied pre or post emergence to transgenic and non transgenic crop varieties. Directed application of glyphosate can be safely made with shielded nozzles which prevent contact of this herbicide with the crop (Howell and Frans,1980). Best weed control was achieved with post emergence application of glyphosate 1.0 kg/ha as reported by Raja Rajeswari and Charyulu (1996). Glyphosate applied using hooded sprayer provided better weed control (Hawf *et al.,* 1996). Soil application of fluchloralin 1.0 kg followed by foliage spray of glyphosate 0.5 kg at 35 DAS gave the best weed control and best yield in Cotton (Patil *et al.,*1997). Satao *et al.,*(1998 a) reported that the non- selective, non-residual herbicide, Basta (glufosinate ammonium) could be used selectively against weeds in cotton when applied with a hood at 30 DAS and concluded that Basta at 375 g/ha and 450 g/ha was equally effective as paraquat 600 g/ha. Trifloxysulfuron-sodium is a broad-spectrum post emergence herbicide for cotton and sugarcane crop at 7.5 to 15 g/ha and cotton injury was not visibly apparent at six to eight weeks after treatment (Porterfield *et al.,* 2002).

Cotton is a widely spaced crop and hence , the late emerging weeds and perennial weeds that are not being controlled by pre-emergence herbicides can be controlled using nonselective post-emergence herbicides with adequate care using shield or hood so that the herbicide is directed only on weeds without any drift towards cotton crop.

Herbigation : To apply preemergence herbicide on third day of cotton sowing, application of herbicides through drip as herbigation is not advantageous than conventional method due to improper wetting of dry soil under herbigation. However, for post emergence application of residual herbicides, herbigation is found to be the best method than conventional spraying due to thorough wetting and uniform spread of herbicide molecules under herbigation than under conventional spraying. Hence, for managing weeds under irrigated cotton, herbicide rotation and herbigation are the novel approach and is safe to soil micro flora and succeeding pulse crop (Nalayini *et al.,* 2013).

Integrated weed management : Weed problem is more acute and hazardous due to inadequate field preparation, inefficient weeding during incessant and heavy rains, non availability of labour for timely removal of weeds, inefficient implements etc.,. Therefore an integrated approach of weed management involving herbicides and cultural methods will be effective in controlling weeds. The effect of chemical weed control measure can be strengthened by supplementing with certain mechanical measures and *vice versa.* Herbicides supplemented with an interculture were in a position to enhance the cotton yield by 2 to 2.5 times than either alone (Shelke and Bhosle,1989).Pendimethalin 1.5 kg /ha with one hand hoeing at 45 DAS provided similar yields of seed cotton as that obtained in weed free check (Panwar and Malik,1991).

Chandi *et al.,* (1993) observed that pre-emergence pendimethalin 1.0 to 1.5 kg /ha with one hand weeding 6 weeks after sowing resulted in the highest seed cotton yields. Fluchloralin, pendimethalin, butachlor and diuron as pre-emergence spray followed by interculture and hand weeding recorded higher *kapas* yield over sole application of paraquat and glyphosate as post-emergence spray (Raja Rajeswari and Charryulu,1996). At hilly zone of Karnataka, clomozone 1.5 kg a.i./ha + hand weeding was the best treatment in controlling weeds and produced higher seed cotton yield (Madiwaler and Prabhakar,1998).Glyphosate at 1.0 kg as directed spray on 20 DAS using hood followed by one hand weeding at 45 DAS recorded the lowest weed DMP on 60 DAS (Nalayini *et al.,*1999 a) and nutrient uptake by weeds on 90 DAS (Nalayini *et al.,*1999 b).Highest seed cotton yield with Pendimethalin 1.5 kg as pre-emergence followed by one hoeing as reported by (Brar *et al.,*1999).According to Sreenivas (2000) alachlor at 2 kg/ha and diuron at 0.75 kg/ha plus glyphosate at 1.5 kg/ha recorded better weed control in cotton. Pendimethalin 1.0 kg as pre emergence herbicide followed by one hand weeding at 35- 40 DAS and mixture of pyrithiobac sodium 50g + quizalofop ethyl 50 g on 60 DAS was found to be efficient and more economical for managing weeds of irrigated cotton (Nalayini *et al.,* 2012)

Stale seed bed technique : A stale seed bed is a seedbed which has been prepared and given a false start some weeks before the seed is due to be sown, any weed seeds in the bed will be encouraged to emerge and grow so that they can be raked out and killed before the actual cotton crop is sown. This technique reduces the number of weeds which have to be controlled when the cotton seedlings start to grow in the field. Stale seedbeds are established several weeks or months before planting (Hydrick and Shaw (1994), Minton *et. al.*, (1989). Stale Seed Bed Technique (SSBT) using a mixture of pendimethalin 1.0 kg.a.i + glyphosate 1.0 kg.a.i./ha one week after pre sowing irrigation (one week before sowing) recorded the highest weed control efficiency of 85.2 per cent on 35DAS (Nalayini and Suveetha (2012).

A perusal of the above literatures suggests that integrated approach is the most effective approach for controlling weeds in cotton.

Biotechnology applications in chemical weed management

Herbicide tolerant genetically modified crops : Recently, genetically modified crop varieties with two biotech traits (stacked trait crops) have been made commercially available and currently cultivated in several countries. Stacked trait products are mainly represented by plants that have been genetically modified to exhibit tolerance to glyphosate or glufosinate and resistance to lepidopteran pests. Before the emergence of plant genetic engineering, option for selective crop protection against herbicides was limited. Development in plant genetic engineering and knowledge of biochemical action of herbicides on plants spurred innovative approaches to engineer crops to withstand herbicides. These strategies usually involve isolation and introduction of a gene from other organisms, mostly bacteria which is able to overcome the herbicide induced metabolic blockage. Tolerance to herbicide glufosinate (Basta ^{R})is conferred by the bacterial gene bar, which metabolizes the herbicide into non toxic compound (Thompson *et al.,*1987). Glyphosate resistance is achieved by the introduction of either Agrobacterium gene from CP_4 that codes for a glyphosate insensitive version of the plant enzyme,EPSP Synthase or gox gene from *Achromobacter,* which codes for a glyphosate oxireductase in the breakdown of glyphosate . A number of other genes have been identified that can alleviate the herbicide action through various ways (such as detoxification, sequestration etc.,) and thus confer resistance to the plants carrying them. Thus genetic engineering technology has made it possible to tailor crop varieties to resist specific herbicides by introducing relevant genes. HTGM crops will allow farmers total control of weeds. HTGM crops are gaining farmers' acceptance because of several advantages such as increased flexibility to manage problem weeds, prevention of multiple use of herbicides, reduction in total herbicide use, greater adoption of conservation tillage, less herbicide carry over etc.,

Concerns and apprehensions of HTGM crops : The use of herbicide resistant crops undermines the possibilities of crop diversification, thus reducing agro biodiversity in time and space (Altieri,1994).Effects of introduction of herbicide resistance crops on biodiversity also reported by (Amman,2005), escape of transgenes from HTGM crops, non selective herbicides may wipe out all vegetation except the HTGM crops, development of herbicide resistance in weeds, shift in weed flora etc., There is potential for herbicide resistant varieties to become weeds in other crops (Holt and Le baron,1990). The HTGM crops may replace labour and deny rural woman the livelihood as most of the weeding is done by them (Varshney and Naidu,2009).Also in countries like India where multiple crops are grown such as under intercropping system wherein compatible intercrops are grown with cotton, the use of HTGM technology is not possible. *Bt* resistance and herbicide resistance are qualitatively different. If insects develop resistance against a particular *Bt* toxin, alternative *Bt* toxin with different modes of action or target sites can be deployed. Various strategies such as pyramiding of different *Bt* genes and maintaining refugia have been suggested to delay development of resistant insects. Similarly, strategies have been defined to delay development of herbicide resistance weeds in the case of conventional crop varieties. These include, combined or sequential use of herbicides with different mode of action, crop rotation, integrated weed control etc., (Das and Duary,1999) and combining non chemical approaches like crop rotation, cultivation, mulching with organic and inorganic materials and solarization helps in managing herbicide resistance development (Timothy et al 2000).In the case of genetically engineered HTGM varieties, these strategies are less relevant. When the herbicide could be applied at various stages of crop growth, farmers may not opt for integrated weed control measures. Similarly, when different crops carry engineered resistance to the same herbicide, use of different herbicides may not remain an option .Once the weeds develop resistance, through either acquisition of the gene from the HR variety or by mutation, they will remain resistant against the herbicide. Replacement of the herbicide is the only option in such a scenario. Since development of new and safer herbicides is time and resource demanding, development of new herbicides is not likely to keep pace with emergence of HR weeds. A major current concern with the introduction of glyphosate or glyufosinate resistant transgenic crops is that if the weeds develop resistant, these environmentally benign herbicides will become ineffective and will force use of other less desirable herbicides for weed control. Already, glyphosate resistant *Lolium* populations have emerged in Australia (Powels *et al.,* 1998), USA (Simarmata *et al.,* 2001) and South Africa (Cairns *et al.,* 2001).Further, glyphosate resistance has also been recorded in *Eleusine indica* in Malaysia (Lee *et al.,*1999; Tran *et al.,* (1999), *Lolium multiflorum* in Chile (Perez and Kogan, 2003) and *Conyza Canadensis* (Van Gessel, 2001 ; Mueller *et al.,* 2003)

Thus as technology, herbicide resistant crops offers opportunity for efficient control of weeds. However, doubts remain about the long term viability of this strategy, especially the emergence of herbicide- resistant weeds following wide spread cultivation of HRGM crops and the best herbicides may not be available even for conventional weed control (Bhat and Chopra,2006).

Nano Agrobiotechnology and weed management : Systems of Controlled liberation (SCL) represent an alternative to the conventional systems of herbicide application. This process is defined as “ a technique or method where the active agent is available for a specific product to a speed and duration designed to achieve the intended effect (Scher,1999).The herbicide SCL is a technology wherein an active ingredient is available for a specific goal at a concentration and with a duration designed to achieve the intended effect, aiming to reach optional biological effectiveness and to reduce any harmful effects (Ruegg *et al.,*2007 : Undabeytia *et al.,* 2004 : Fernandez – Perez, 2007). Reducing herbicide levels also reduces costs for farmers as well as for companies (Markus,1996).Reduction in volatilization loss of applied herbicides due to micro encapsulation has been reported thus diminishing the presence of herbicide in the atmosphere (Whienhold and Gish, 1994 : Dailey, 2004) , reduction in phyto toxicity in crops due to micro encapsulation has also been reported (Bernards *et al.,*2006).Micro-encapsulation has been proven to improve pesticide effectiveness in comparison to commercial formulations (Greene at al., 1992 ; Vasilakoglou and Eleftherohorinos, 2003 ; Hatzinikolau *et al.,*2004, Sopefia *et al.,* 2007, 2008). Development of nanoherbicide to penetrate cells is under development jointly by Agricultural Rresearch Institute in Mexico and India that would attack a weed’s seed coating ,germination of weeds would be prevented and the seed would thus be destroyed even when it is buried deep in soil, below the reach of tillers and conventional herbicides because soil particles would not be able to stop the minute herbicide nanoparticle from migrating down.Breaking the dormancy of Cyperus rotundus usng zinc oxide nanoparticles at 3g/ kg of tubers for the management of wCyoerus rotundus has been reported (Viji and Chinnamuthu, 2015).

The perusal of the literatures on micro encapsulation of herbicides show that in future controlling weeds with micro encapsulated herbicides will be the potential technology to achieve season long weed control with lesser costs and risks to the environment.

Introgression of crop genes and trangenes into weeds : Gene flow between transgenic crops and conventional varieties or their wild relatives has been cited as one of the central ecological risks associated with the application of biotechnology to crop production (NRC, 2000). Primary concerns of ecologists have been that genes conferring insect resistance might increase ûtness, competitive ability, and invasiveness of the crop itself, or cause increased invasiveness of wild crop relatives that may obtain the trait through hybridization and subsequent gene ûow (Kareiva *et al.,*1994, Hails, 2000).Assessing gene flow consequences is challenging, because it is difficult to predict the ecological effects of transgenes that are integrated into different genetic backgrounds or expressed in different ecological contexts. Conner *et al.,* (2003) proposed three potential consequences of gene flow from GM crops: “transfer” of the genes to nearby crops causing the trait to spread (intentionally or unintentionally); “escape” of the insect resistance genes to non-cultivated related species and increase in the potential of insect-resistant versions of crops to become established as weeds.

In cotton, the risk of transfer or escape of the *Bt* gene from *Gossypium hirsutum* to the sexually compatible species could not be ignored. The potential transfer through gene flow from herbicide resistant crops to wild or semi domesticated relatives can lead to the creation of superweeds (Lutman.1999).The weed relatives of Cotton that have been reported are *Gossypium tomentosum* which is found in Hawaii and in India, *Gossypium stocksii* has been reported .Crosses among tetraploid *Gossypium* species can be successful, while crosses between tetraploid and diploid *Gossypium* species are essentially unknown without human intervention (Brubaker *et al.,* 1999).A herbicide resistance trangene alone confers no fitness advantage in areas where the herbicide is not sprayed. If it is transferred from the crop to a related weed species,the biggest concern is for the farmer who must cope with the herbicide resistant weed. An herbicide resistance trangene in a crop can greatly increase the chance of survival of interspecies crosses by eliminating competition of other herbicide susceptible weeds (Keeler *et al.,*1996).If the crop also contains trangenes conferring other survival – enhancing traits, such as resistance to insects and/or pathogens, the resulting cross and further back crosses with the weedy parental species might confer enhanced fitness outside the agricultural setting, resulting in ecological disruption.

Glyphosate and glufosinate – ammonium on soil : Glyphosate and glufosinate herbicides are widely used in weed management and the importance of these two herbicides has increased in the last years due to the increased demand for herbicide – tolerant crops (Shaner,2000). Crops tolerant to these herbicides are the most cultivated genetically modified crops and environmental issues concerning the cultivation of crops tolerant to these herbicides are of current interest (Engel et al ., 2002).Glyphosate and glufosinate are non residual herbicides that degrade readily from soil with estimated half-lives ranging from 7 to 60 days and from 1 to 25 days respectively (Giesy *et al.,*2000). Degradation by soil micro-organism is the predominant way by which these herbicides are metabolized in soil (Tebbe and Reber,1988 ; Giesy *et al.,* 2000). No detrimental effects were observed on soil microbial activity and biomass when glyphosate and glufosinate were applied at normal agricultural rates under laboratory and field conditions (Wardle and Parkinson,1992: Accinelli *et al.,* 2002). According to Wauchope *et al.,* (2001) glyphosate and glyfosinate replace herbicides that are in general more persistent in soil and absorbs less to soil particles.

Herbicides and microorganisms : Intensive cultivation necessarily employs chemical herbicides for effective control of various weeds. In recent days, contamination of environment by these toxic xenobiotics on environment has raised serious concerns all over the world. Despite these concerns newer herbicide molecules are being added regularly. Therefore, issues concerning degradation, detoxification of applied herbicides and use of eco-friendly weed management strategies will receive greater attention now than ever before. Apart from causing pollution, the applied herbicides also have an impact on non target soil microorganisms. Hence, impact of herbicides on soil microorganisms should be an important consideration for employing herbicide in weed management. Strategies for effective weed management must take into account the effect of herbicides on soil borne pathogens,plant growth promoting microorganisms and their saprophytic survival. The involvement of microbial endophytes of weeds need thorough investigation as their role in conferring protection and ecological fitness in weeds has been demonstrated conclusively. Identification and development of native microorganisms with ability to degrade weed seeds to kill the weeds either directly or indirectly or by production of secondary metabolites with herbicidal properties will have relevance in eco-friendly weed management strategies (Patil *et al.,* 2009).

Impact of climate change on weeds and herbicidal weed management

Enhanced CO_2 on weeds : Weeds have a greater genetic diversity than crops. Consequently, if a resource (light, water, nutrients or carbon dioxide) changes within the environment, it is more likely that weeds will show greater growth and reproductive response. It can be argued that many weed species have the C_4 photosynthetic pathway and therefore will show a smaller response to atmospheric CO_2 relative to C_3 crops. However, this argument does not consider the range of available C_3 and C_4 weeds present in any agronomic environment.Today,for all weed/crop competition studies where the photosynthetic pathway is the same, weed growth is favoured as CO_2 is increased. There are some studies (Ziska and Teasdale 2000; Ziska *et al.,* 2004) that demonstrates a decline in chemical efficacy with raising CO_2 .Dilution effect of glyphosate for controlling Canada thistle under elevated CO_2 has been reported (Ziska *et al.,* 2004).Biological control of pests by natural or manipulated means is likely to be affected by increasing atmospheric CO_2 and climate change. Climate as well as CO_2 could alter the efficacy of weed bio control agents by potentially altering the development, morphology and reproduction of the target pest.

Temperature increase on weeds and weed management : Increasing temperature may mean an expression of weeds into higher latitudes or higher altitudes.. With an increase of 3^0 C ,many weeds which are not problematic today may become aggressive as reported for itch grass (Patterson,1995).Weeds being major pests competing for basic inputs with crop and being aggressive have developed all strategies to combat change in climate than crop (Devendra *et al.,* 2009).Witch weed, a root parasite of corn, is limited at this time to the coastal plain of North and South Carolina and with an increase of temperature of 3^0 C, it is speculated that this parasite could become established in the Corn Belt with disastrous consequences. Clearly any direct or indirect impacts from a changing climate will have a significant effect on chemical management. Changes in temperature, wind speed, soil moisture and atmospheric humidity can influence the effectiveness of applications. For example, drought can result in thicker cuticle development or increased leaf pubescence, with subsequent reduction in herbicide entry into the leaf and hence suitable herbicide formulations are to be standardized to make the herbicide enter into the target sites.

The literatures on impact of climate change on weeds clearly suggest that many weeds which are less problematic or sleeper weeds may become aggressive and troublesome weeds due to climatic change and also the weeds may extend their spread to newer areas and hence it is necessary to generate information on these crucial aspects in order to equip ourselves to meet any challenges in weed management due to climate change.

CONCLUSION

In Cotton, The greatest competition from weeds usually occurs early in the growing season. However to harvest clean and uncontaminated fibre, it is essential to keep weed free up to harvest. The mechanical removal of weeds is tedious and costly. Although, the pre-emergence or pre plant incorporated herbicides take care of weeds during early days, the late emerging weeds are to be controlled by mechanical or directed application as we do not have selective and safe herbicides. Micro encapsulated nano herbicide formulations have potential in future weed control programme. In most major crops, stacked genes technology widen the options for efficient and economical pest management and strongly impacting weed management choices in short to medium term. However, in long term, the problems due to herbicide resistance and super weeds as a result of this technology will be a serious threat if the traditional resistance management strategies like, crop rotation, cultural methods, non chemical approaches and herbicide rotation are not followed. However, HTGM crops offer farmer a powerful new tool that can be incorporated into an integrated pest management strategy which can be used for many years for managing weeds economically and effectively. In future, nanotechnology offers opportunity and potential in scientific weed management.

REFERENCES

Accinelli,C., Screpanti,C.,Dinelli,G. and Vicari. A. 2002. Short – time effects of pure and formulated herbicides on soil microbial activity and biomass. *Intern. J. Environ. Anal. Chem.* **82 :** 519-27.

Akhtar,M.,Hassan,Y.,Nazir,M.S.and Cheem, Z.A. 1986. Seed Cotton yield and weed population in response to pre and post emergence application of herbicides. *J. Agril. Res.* **24 :** 197-202

Amman,K.2005. Effects of biotechnology on biodiversity:herbicide-tolerant and insect resistant GM crops. *Trends Biotechnol.,* **23 :** 388-94.

Annon, 2015. International survey of herbicide resistant weeds,October **12,** 2015.

Allen,R.L.,Snipes,C.E. and Crowder,S.H.1997. Fruiting response of cotton (*Gossypium hirsutum*) to pyrithiobac. *Weed Technol.* **11 :** 59-63

Altieri, M.A. 1994. Biodiversity and pest management in agroeco systems.Boulder Co : West view press.

Balyan, R.S.,Bhan,V.M.and Malik,R.K.1983. The effect of weed control at different times on the yield of seed cotton. *Cotton Dev.,* **13 :** 9-10.

Bernards,M.L.,Simmons,J.T.,Guza,C.J., Schulz,R., Penner,D.and Kells, J. J. 2006. Inbred corn response to acetanilide herbicides as affected by safeners and micro encapsulation. *Weed Tech.* **20 :** 458- 65.

Bhat,S.R. and Chopra,V.L.2006. Choice of technology for herbicide – resistant transgenic crops in India : Examination of issues. *Curr. Sci.,* **91 :** 435- 38.

Brar,A.S.,Thind,R.J.S. and Brar, L.S, 1999. Integrated weed management in American cotton. *J. Res. Punjab Agric.Univ.* **36 :** 194-98.

Brubaker, C.L., Bourland, F. and Wendel, J.F. 1999. The origin and domestication of cotton. In: Smith, C. and Cothren, J. (eds) Cotton: Origin, History, Technology, and Production. John Wiley & Sons, New York, pp. 3–31.

Cairns,A.L.P. and Ecksteen,F.H.2001. Glyphosate resistance in *Lolium rigidum* (Gaud). in South Africa. In Resistance 2001, Abstr. Rothamsted, UK.

Chandi,J.S.,Sandhu,K.S.and Singh,T.1993. Weed management in American Cotton (*Goyssypium hirsutum* L.).In: Integrated weed management for sustainable agriculture. *Proc.Indian Soc.Weed Sci.International Symposium,* 18-20 November, Hisar, India.

Chandler,J.M.1984. Cotton protection practices in the USA and World,Section D: Weeds. In :Kohel,R.J. and Lewis,C.F (ed.) "Cotton", *Am. Soc. Agron.* Madison,USA, pp.330-365.

Conner, A.J., Glare, T.R., and Nap, J.P. 2003. The release of genetically modified crops into the environment. Part II: Overview of ecological risk assessment. *The Plant Journal* **33 :** 19–46.

Dailey,O.2004. Volatilization of Alachlor from Polymeric Formulations.*J.Agric.Food Chem.* **54 :** 6742 -46.

Das,T.K. and Duary.1999. Herbicide Rresistance in Weeds : Current Scnario,Mechanisms and Management Strategies for Now and Future. *Ann. Agric. Res.* **20 :** 393-98.

Devendra,R., Naidu,V.S.G.R., Ramachandra Prasad,T.V. and Varshney,G.Jay.2009. Weeds under climatic change. In : Proc.National Symposium on Weeds Threat to Envirnment,Biodiversity and Agriculture productivity,August 2-3,2009.Tamil Nadu Agricultural University, Coimbatore.pp 160.

Douti, P.Y.1995. Cotton for weed control: When is the weed competition period? *Agric.Et Development,* **7:** 31-36.

Engel, R.H.,Frenzel,T. and Miller,A.2002. Current and future benefits from the use of GM technology in food production. *Toxicol. Lett.* **127 :** 329-36.

Fernandez – Perez, M.2007. Controlled release systems to prevent the agro-environmental pollution derived from the pesticide use. *J.Environ.Sci.Health* **42 :** 857-62.

Giesy,J.P.,Dobson,S. and Solomon, K. R. 2000. Ecotoxicological risk assessment for Roundup ™ herbicide. Rev. Environ. Contam. Toxicol. **167 :** 35-120.

Greene,L.C., Meyers.P.A., Springer,J.T.and Banks,P.A.1992. Biological Evaluation of Pesticides Released from Temperature Responsive Micro capsules. *J.Agric.Food Chem.* **40 :** 2274-78.

Hails, R. S., 2000. Genetically modiûed plants — the debate continues, *Tree*, **15 :** 14

Hatzinikolaou, A.S., Eleftherohorinos, I.G.and Vasilakoglou, I.B. 2004. Influence of Formulation on the Activity and Persistence of Pendimethalin, *Weed Technology.* **18 :** 397-403.

Hawf,L.R.,Wright,D.L..and Gingerich, L. 1996. Roundup applied by hooded sprayer versus cultivation in cotton. In : *"Proceedings Belt Wide Cotton Conference"* **2 :** 1558-59.

Heap, I. 2004. International survey of herbicide resistant weeds.(www document), URL.(http:// www.weedscience.com)

Holt, J.S. and Le Baron, H.M.1990. Significance and distribution of herbicide resistance. *Weed Technology.* **4 :** 141-49.

Howell, S . and Frans,R.1980. Preliminary studies on control of Bermuda grass in Cotton.In : *"Proceedings of the 33 rd annual Meeting of the Southern Weed Science Society"*,p.29.

Hydrick D E ,Shaw D R .1994. Effects of tank-mix combinations of non selective foliar and selective soil-applied herbicides on three weed species. *Weed Technol.* **8** : 129- 33.

Joshi, M.1997. *"Hybrid Cotton in India"*,Kalyan Publishers,Ludhiana,p.191.

Kareiva, P., Morris, W., and Jacobi, C. M. 1994. Studying and managing the risks of cross-fertilization between transgenic crops and wild relatives, *Mol. Ecol.* **3 :** 15-26.

Keeler,K. H., Turner, C. E. and Bolick, M.R. 1996. Movement of crop transgenes into wild plants.In : *Herbicide resistant crops – agricultural,environmental,economic,regulatory and technical aspects* (ed.)S.O.Duke,303-330.Chelsea,MI : Lewis Publishers.

Lee,L.J.1999. Glyphosate – resistant genotypes (*Eleusine indica*) in Malaysia and some of its morphological differences.In Proceedings of the 1999 Asia – Pacific Weed Science Congress, Bankok,Thailand,1999. pp. 527-36.

Lutman, P.J.W.1999. Gene flow and agriculture: relevance for transgenic crops. British Crop Protection Council Symposium Proc. **72 :** 43-64.

Madiwaler,S.L.and Prabhakar,A.S.1998. Effect of method of sowing and weed management treatments on growth and yield of hybrid cotton in hill zone.*Karnataka J.Agric.Sci.* **11 :** 8-11.

Manjunath,S.and Y.C.Panchal.1989. Growth and yield components of cotton as influenced by herbicides. *J.Maharshtra Agric.Univ.***14 :**181-83.

Markus.A.1996. Advances in the technology of controlled-release pesticide formulations. 73-91 pp. In: Benita S. (eds.) micro encapsulation : methods and industrial applications. Marcel Dekker,New york.

Minton B W., Shaw D R and Kurtz M E. 1989. Post emergence grass and broadleaf herbicides interactions for red rice (O*riza sativa)* control in soybean (*Glycine max*).Weed Technol. **3** : 329-34.

Mueller,T.C.,Massey,J.H., Hayes,R.M., Main,C.L and Stewart,C.N.2003. Shikimate accumulates in both glyphosate – sensitive and glyphosate resistanthorseweed (*Conza canadeni*s L. Cronq.) *J.Agric.Food Chem.* **51 :** 680-84.

Nalayini, P., Kandasamy, O.S. and Balasubramaniyan 1999 a. Density and Dry matter Production of Weeds as Influenced by Cotton Hybrids – levels and Weed Control Methods.*World Weeds.* **VI :** 37- 45.

Nalayini,P., Kandasamy, O. S. and Balasubramaniyan 1999 b. Influence of Cotton Hybrids,N levels and Weed Control Methods in Nutrient Depletion By Weeds. *World Weeds.* **VI :** 179-84.

Nalayini, P., Kandasamy,O. S. and Balasubramaniyan 2001. Production potential and nitrogen – use efficiency of inter-specific and intra – *hirsutum* Cotton hybrids under graded levels of nitrogen and weed – control methods. *Indian Journal Agronomy.* **46 :** 557-62.

Nalayini, P., K Sankaranarayanan and K Velmourougane 2013. Herbigation in cotton (*Gossypium* spp): Effects on weed control, soil microflora and succeeding green gram (*Vigna radiata*) *Indian Journal Agricultural sciences* **83 :** 1144–48

Nalayini, P and M.Suveetha.2012. Stale seed bed technique –a novel approach for managing weeds in irrigated cotton based intercropping system. In : International Symposium papers on *"Global Cotton Production Technologies vis-a-vis Climate Change"* held during 10-12 October,2012 at CCS Haryana Agricultural University, Hisar,pp 301-304.

Nalayini, P. K. Sanakaranarayanan and K. Velmourougane 2012. Herbicide mixtures and herbicide rotation for efficient, economical and broad spectrum weed control in winter irrigated *Bt* Cotton of southern India. *"Third International Agronomy Congress"* held during November 26-30,2012 at New Delhi. In: Proceedings of Third Agronomy Congress, PP.709-711

Panwar ,R.S. and Malik,R.K.1991. Competition and Control of weeds in Cotton.*Haryana Agric.Univ.J.Res.,* **21 :** 226-34.

Panwar, R. S., Malik, R. K., Bhan,V. M. and Malik, R.S. 1989. Evaluation of pre emergence and post –emergence herbicides in Cotton. *Haryana Agric.Univ.J.Res.,***19 :** 235-39.

Parshutin, S., Kuryanov, V. and Zabalueu, I. 1980. Prowl- a new promising herbicides .*Khlopkovodstuo.* **4 :** 27.

Patterson,D. T. 1995. Weeds in a changing climate. *Weed Science*, **43 :** 685-701.

Patil, B.M., Satao, R. N. and Lahariya, G. S. 1997. Integrated weed management in Cotton.*PKV Res. J.* **21 :** 220-21.

Patil, C. R., Jones Nirmalnath, P., Agasimani, C. A. and Doddagoudar, C. K. 2009. Microorganisms and herbicides: relevance in weed management.

Perez,A.and Kogan,M.2003. Glyphosate – resistant horseweed from Delaware. *Weed Sci.,* **49 :** 12-19.

Powles, S. B., Lorraine–ColWill, D. F., Dellow, J. J. and Peterson,1998. Evolved resistance to glyhosate in rigid ryegrass (*Lolium rigidum*) in Australia.*Weed Sci.* **46 :** 604-07.

Porterfield,D.,Wilcut,J.W., Clewis,S.B.and Edmisten. 2002. Weed – free yield response of seven cotton (*Gossypium hirsutum*) cultivars to CGA – 362622 post emergence. *Weed Technol.***16 :**180-183.

Raja Rajeswari,V.,Charyulu,N.R.1996. Integrated weed control in Cotton. *Ann. Agric. Res.,* **17 :** 438-40.

Ramussen,K.,Chemin,P.,Haastrup,P.1999. Regulatory requirements for biocides on the market in the European Union according Directives 98/ 8/EC. J. hazard.*Mater* **67 :** 237-51.

Rout,D.and Satapathy,M.R.1998. Chemical weed control in rain fed cotton *(Gossypium hisutum L.*). *Indian J.Agron.* **43 :** 348-50.

Ruegg, W.T., Quadranti. and Zoschke A. 2007. Herbicide Research and Development. Challenges and Oppurtunities. *Weed Res.* **47 :** 271-75.

Sanbagavalli,S.,Kandasamy,O.S.,Selvi,R.V. and Ganesaraja,V.2009. Effect of stale seedbed technique of weed management on weeds and yield of cotton. In : Proc.National Symposium on *"Weed Threat to Envirnment,Biodiversity and Agriculture Productivity",* August 2-3,2009.Tamil Nadu agricultural University, Coimbatore.pp 160.

Saraswat, V.N. 1989. Project coordinator's report 1.1.1989 to 31.12.1989.All India Co-ordinated Research Programme on weed control. Jabalpur, India. pp,218.

Satao,R.N.,Patil,B.M. and Karunakar,A.P.1998 a. Evaluation of basta in Cotton. *Pestology,* **XXII :** 48-54.

Satao,R.N.,Patil,B.M. and Karunakar,A.P. and Nalamvar,R.V.1998 b. Evaluation of glyphosate 41 % SL (Round up) in Cotton by directed post emergence aplication on weeds. *Pestology,* **XXII :** 22-28.

Scher, H.B.1999. *"Controlled-Release Delivery Systems For Pesticides".* Marcel Dekker,New York. 329 pp.

Shaner, D.L., 2000. The impact of glyphosate-tolerant crops on use of other herbicides and on resistance management. *Pest Manag. Sci.* **56 :** 320-26.

Shelke ,D.K.and Bhosle,R.H.1989. Economics of different methods of weed control in rain fed cotton. J.*Maharashtra Agric.univ.,* **14:**205-07.

Shelke,D.K.and Bhosle,R.H.1990. Determination of critical periods of crop weed competition in rain fed cotton. *J.Maharashtra Agric.Univ.***15 :** 257-58.

Simarmata,M.,Kauffmann,J.E.and Penner,D.2001. Progress in determining the origin of the glyphosate – ryegrass in California.In : Proc. Meeting of the Weed Science Society of America.NC,USA. P.95.

Sreenivas,G.2000. Effect of application of glyphosate with or without other pre-emergence herbicides in rain fed American Cotton (*Gossypium hirsutum* L.). *Indian J. Weed Sci.* **32 :** 98-100

Solaiappan, U., Mani, L. S. and Sherif, N. M. 1992. Weed management in Cotton. *Indian J.Agron.* **37 :** 878-80.

Sopefia,F., Maqueda,C. and.Morillo.E.2007. Norflurazon mobility,dissipation,activity and persistence in a sandy soil as influenced by formulation. *J.Agric.Food Chem.* **55 :** 3561-67.

Sopefia,F., Maqueda,C. and.Morillo.E. 2008. Influence of soil characteristics and formulation on alachlor dissipation in soil. *Soil. Sci. Soc. Am. J.* **72 :** 767-74.

Sopefia,F.,Maqueda,C and Morillo.E. 2009. Controlled release formulations of herbicides based on micro-encapsulation. *Cien. Inv. Agr.* **35 :** 27-42.

Sprankle,P.L.1974. AC 92553- a selective herbicide for weed control in cereals and other crops.Pro.12 th *British Weed Control Conf.,* London,UK.pp.825-830.

Swann,C.W.and Wilson,H.P.2001. Cotton weed management. Virginia pest management guide. Virginia co-operative extension 377-395.

Tebbe, C.C. and Reber,H.H.1988. Utilization of the herbicide phosphinothricin as a nitrogen source by soil bacteria. *Appli. Microbiol, Biotechnol.* **29 :** 103-105.

Thind,R.J.S., Brar,A.S.and Brar,L.S.1995. Weed interference in American Cotton (*Gossypium hirsutum* L.) *Indian J.Weed Sci.* **27 :** 71 -74.

Thompson,C.J., Movva,N.R., Tizard,R., Crameri,R., Davies, J.V., Lauwereys,M and Botterman, J.1987. Characterization of the herbicide- resistance gene bar from *Streptomyces hygrocopicus EMBO.J.* **6 :** 2519-23.

Timothy,S.Pather.,Joseph M.Ditomaso.and Jodies S.Holt.2000. Herbicide Resistance : Definition and Management Stretegies. Publication No.8012,University of California, pp 1-14.

Tran, M., Bearson, S., Brinker, R., Casagram,Des L., Falletti,M.and Feng, Y. 1999. Characterization of glyphosate resistant *Eleusine indica* biotypes from Malaysia.In : *"Proc.of the 1999 Asia Pacific Weed Science Society Conference"*, Bangkok, Thailand,1999, pp. 527-36.

Undabeytia,T., Nir,S. and M.J.Gomara.2004. Clay-vesicle interactions : Fluorescence measurements and structural implications for slow release formulations of herbicides. Langmuir **20 :** 6605–10

VanGessel,M. 2001. Glyphosate – resistant horseweed from Deltaware. *Weed Sci.* **49 :** 703-05.

Varshney, G.Jay. and Naidu,V.S.G.R.2009. Herbicide tolerant genetically modified crops – prospects in India. In : Proc.National Symposium on "*Weed Threat to Environment,Biodiversity and Agriculture productivity"*, August 2-3,2009.Tamil Nadu gricultural University, Coimbatore.pp 160.

Vasilakoglou,I.B.and Eleftherohorino, I. G. 2003. Persistence,efficacy,and selectivity of amide herbicides in corn.*Weed Technol.***17 :** 381-88.

Viji,N and C.R.Chinnamuthu 2015. Breaking Dormancy and inducinggermination of the world worst weed the C yperus rotundus using nanoparticles. *Ann. Plant Soil Res.* **179**special issue) : 361-363

Vireshwar Singh and Verma, SS.1988. Drymatter production, nutrient uptake and nitrogen recovery by cotton under weed control and nitrogen treatments. *J.Indian Soc.Cotton Improv.,***13 :** 28-32.

Wardle,D.A. and Parkinson,D.1992. Influence of the herbicides 2,4- D and glyphosate on soil characteristics on persistence of alachlor. *Pestic. Sci.* **35 :** 109-116.

Warrick, B. E. 1996. Post emergence application of staple for broadleaf weed control in the southern rolling plains of Texas.In : *“Pro.Beltwide cotton conferences”,* Nashville, TN, USA, January 9-12, 1996. Vol.2, Mephis, USA : National cotton council :1522-24.

Wauchope, R. D., Estes,T.L.,Allen,R., Baker, J. L., Hornsby, A. G., Jones, R. L. Richards, R. P. and Gustafson, D. I. 2001. Predicted impact of transgenic, herbicide tolerant corn on drinking water quality in vulnerable watersheds of the mid-western USA. *Pest Manag. Sci.* **58 :** 146-60.

Whienhold,B.J.and Gish,T.1994. Chemical properties influencing rate of release of starch encapsulated herbicides : implications for modifying environmental fate. *Chemosphere* **28 :** 1035-46.

Ziska,L.H. and Teasdale,J.R .2000. Sustained growth and increased tolerance to glyphosate observed in a C_3 perennial weed ,quackgrass (*Elytrigia repens* (L.) Nevski), grown at elevated carbon dioxide. *Australian Journal Plant Physiology* **27 :** 159-64.

Ziska,L.H., Faulkner,S.S. and Lydon, J.2004. Changes in biomass and root :shoot ratio of field- grown Cannada thistle *(Cirsium arvense*),a noxious,invasive weed,with elevated CO_2 : implications for control with glyphosate. *Weed Science* **52 :** 28-32.

12

Does *Bt* cotton differ from conventional cotton on agronomic requirement ?- A Review

K.SANKARANARAYANAN AND P.NALAYINI

Central Institute For Cotton Research, Regional Station, Coimbatore 641003.

E-mail : sankaragro@gmail.com

Cotton, being the major fibre crop in India and world, has exercised a profound influence on man and matters. Amongst the cotton growing countries, India occupies the foremost position in terms of its acreage, extending over 12.7 mi ha with production of around 373.9 lakh bales. Before the *Bt* cotton era the excessive and indiscriminate use of pesticides had caused insecticide resistance in major pests like bollworms and emergence of secondary pests in epidemic form making the cotton production risk prone compared to other crops (Kranthi *et al.,* 2002). *Bt* cotton has inbuilt resistance of bollworm due to the *Bt* gene, thus protect early formed bolls and kept intact in the plant. *Bt* cotton is gaining popularity with farmers because of effective control of bollworm complex besides higher productivity (Fitt *et al.,* 1994; Flint *et al.,* 1995; Harris *et al.,* 1996) and ultimately resulted an expansion of area under *Bt* cotton in India from 38,000 ha in 2002 to 11.6 Mio ha in 2014 (Clive 2014).

Agronomic performance of *Bt* transgenic cultivars may vary substantially from their non transgenic counterparts. The expression of transgene can be influenced by transgene x genetic background effects (Sachs *et al.,* 1998) and the transformation techniques randomly incorporate a gene into the host (Altman *et al.,* 1991). When a transgene is introgressed into an elite genetic background, the agronomic performance may be altered because of all the donor DNA from the originally transformed line is not eliminated through back crossing (Falconer, 1989). Introduction of the *Bt* gene altered the morphological, phenological and physiological characteristics of the introgressed cultivars as reported by Venugopalan *et al.,* 2009.

Bt cotton hybrids are compact and relatively early maturing than isogenic non *Bt*. The *Bt* hybrids have an optimum number of functional leaves and are more efficient in converting assimilates to the cotton bolls. As a result, *Bt* cotton hybrids retain more bolls/plant and simultaneously with less boll locule damage resulting in an overall yield advantage. Chen *et al.,* (2012) reported that the *Bt* isogenic line had higher rate of effective bolls. The *Bt* isogenic line had higher Chl a/b, soluble protein, P and Cu at boll setting stage (BSS) and . at initiation of flowering stage (IFS) had significantly higher concentrations of Ca, Mg, Cu, Zn, Mn and Fe, whereas it had lower in concentrations of P, K and B at IFS, and K, S, Zn and Fe at BSS. Wude Yang *et al.,* (2012) that the concentration of the *Bt* protein in the rhizosphere soil reached a peak at 56.14 ng g”1 during the flowering period. However, the *Bt* protein would not continuously accumulate in the soil. The rhizosphere soil of was more suitable for the growth and proliferation of bacteria and fungi but it had no significant impact on the number of actinomycetes.

Additionally *Bt* cotton varying from non *Bt* with respect to retention of early formed bolls, synchronous bursting, lower bad *kapas* content and less labour required for harvest. To utilise the full potential of the *Bt* technology, the advantages associated with these hybrids have to be exploited by modifying or refining the existing agronomic practices to suit different cotton production domains, besides managing limitation like reddening and pre mature senescence associated with *Bt* cotton hybrids.

Compact growth : Growth and development has a direct bearing on reproductive efficiency and seed cotton yield. *Bt* hybrids recorded 6.95per cent less plant height, 10.81per cent less leaf area index (LAI) than non *Bt* hybrids (Rekha, 2007). Plant height and dry matter accumulation, by the Bunny *Bt* was found to be significantly lower , while number of bolls and seed cotton yield were significantly higher than Bunny non-*Bt* (Sunitha et al .,2010).Root volume was significantly higher in *Bt* than non-*Bt* isogenic lines (Sarkar *et al.,* 2008). *Bt* recorded a mean of 25.1 bolls, while it was only 8.8 in non-*Bt* cotton hybrids. Numerically 18.5per cent higher number of squares was observed in *Bt* hybrids. At Coimbatore, non-*Bt* hybrids recorded 40per cent higher LAI and increased plant heights than *Bt* hybrids under rainfed condition (Sankaranarayanan *et al.,* 2011). The *Bt* hybrids were short statured as reported by Mayee *et al.,* 2004. Further study at Nagpur and Coimbatore revealed that less dry matter production, shorter in stature with lesser LAI in *Bt* hybrid as compared to non *Bt* counterpart (Anonymous, 2002).

Compact growth of *Bt* hybrids required reduced spacing and reduction of 15 cm from existing spacing, realized yield advantage of 2.5 q /ha with *Bt* hybrid under front line demonstrations conducted at Chandrapur and Yeotmal districts of Maharashtra with boll guard II during 2007 and 2008.

Apparently from the above observations, the dwarfness in *Bt* might have resulted due to individual or combined effect of transgene x genetic x environment interaction or utilization of more nutrient energy (sink strength) for the nourishments of (maximum) of bolls that were free from bollworm damage due to active expression of *Bt* toxin. In other words, retaining of early formed bolls, prevented from attack by bollworms as a result of inbuilt protection mechanism or individual or combined effect of transgene x genetic x environment had suppressed the vegetative growth parameters including plant height, LAI and monopodia branching but at the same time harnessed the reproductive parts especially developing squares and harvestable maturing bolls in *Bt* cotton. Non-*Bt* hybrid, because of absence of *Bt* gene, was susceptible to bollworm damage and frequently losing the early formed square and bolls and therefore has been induced to grow vegetatively to make compensation for the lost squares and bolls by further branching and axils production to accommodate new squares. Thus, the unique nature of the *Bt* hybrids capable of retaining early produced bolls therefore, shows limited canopy growth and thus occupies less land when compared to non-*Bt* hybrids, keeping the land mass unutilized and offers chance for growth of weeds. Therefore, alterations in row and plant to plant spacing is much essential to better utilize the land and offers the chance for enhanced production and productivity of cotton. The space may also be utilized for accommodating higher population or intercropping tactics also, a practice that enhances the farmers’ income base besides a better pest management tool too.

Early maturity : Inbuilt resistance to bollworm complex leads to retention of early formed fruiting parts that might have pronounced earliness in *Bt* cotton hybrids (Anonymous 2002; Mayee and Rao 2002, Venugopal *et al.,* 2004) and at least 20-30 days early maturity advantage is prevalent with *Bt* cotton hybrids than their non-*Bt* counterparts (Mayee *et al.,* 2004).Higher sink in *Bt* cotton leads to lower source to sink ratio, faster senescence and crop maturity compared to the non *Bt* version (Hebbar *et al.,*2007). Sometimes, the increased assimilate demand of early high fruit retention reduces the resources for continued growth and fruiting, leading to early maturity and reduced yields (Bange *et al.,* 2008).Rekha (2007) observed that *Bt* hybrids matured five days early compared to non-*Bt* hybrids. Bartlett's earliness index of 0.80 with *Bt* hybrids when compared to 0.67 for conventional hybrids was observed (Deosarkar, 2004) (Table 1) and also in another study a 10per cent increase in earliness index of *Bt* hybrids (0.7) than non-*Bt* hybrids (0.64) is reported (Sankaranarayanan *et al.,*2011b*)* as influenced by the early boll setting and boll opening . These studies concluded that *Bt* is maturing earlier than non *Bt*. This earliness associated with *Bt* hybrid could be exploited under cotton based cropping system for timely sowing of succeeding winter wheat and other crops in North and Central zones of India, rice in south zone and also to achieve yield maximization through rotational crops.

Agronomy practices : The yield losses is due to climatic aberrations are higher in cotton (60per cent) as compared to other crops like cereals, oilseeds and pulses (30per cent) (Dason, 1996). The high sensitivity of *Bt* hybrids to leaf reddening induced by drought and low temperature indicates that *Bt* cotton hybrids are more influenced by climate.

Soil : In India, *Bt* cotton is grown in varied soils from deep heavy vertisol to sandy loam alluvium soil. In areas like Maharastra and Madya Pradesh, *Bt* cotton is grown on large scale in shallow black soil with low fertility levels and moisture retaining capacity. In the south zone, *Bt* cotton is grown in hot semi arid regions, both under rainfed and irrigated conditions in

Table 1. Yield and earliness index of *Bt* and non *Bt* hybrids

Non *Bt* hybrids	Yield (kg/ha)	Earliness index	*Bt* hybrids	Yield (kg/ha)	Earliness index
Akka non *Bt*	1545	0.57	Akka *Bt*	2681	0.78
Ankur 2534 non *Bt*	1105	0.73	Ankur 2534 *Bt*	1561	0.82
Bunny non *Bt*	1879	0.73	Bunny *Bt*	2221	0.84
Ankur 2226 non *Bt*	716	0.67	Ankur 2226 *Bt*	1325	0.76
Mean non *Bt*	1331	0.68	Mean *Bt*	1947	0.80

Source: Adapted from Deosarkar (2004)

Table 2. Seed cotton yield of MECH 162 *Bt* hybrid under different situations*

Genotypes	Deep soil +HR	Deep soil + LR	Medium soil + HR	Medium soil + LR	Shallow soil + HR	Shallow soil + LR
MOL 2463	1139	1120	1207	879	1244	802
NHH 44	1058	1500	1107	840	1055	612
MECH 162 *Bt*	1263	1580u	1340	1259	1655	1347

Bhatade *et aI.,* (2006) *High rainfall=HR and Low rainfall=LR

Table 3. Influence of soil depth on the yield of *Bt* and non *Bt* hybrids

Parameters	MECH 184 *Bt*	MECH 184 non *Bt*	MECH 162 *Bt*	MECH 162non *Bt*	MECH 12 *Bt*	MECH 12 non *Bt*	NHH44
Shallow	18.25	13.6	18.53	16.0	11.75	15.2	12.8
Medium deep	21.14	14.18	21.26	14.35	17.7	14.1	11.25

Jagvir Singh *et aI.,* (2004)

medium black soil, red and black soil and coastal alluviums. While assessing the performance *Bt* hybrid in deep, medium and shallow soils combined with high and low rainfall under Marathwada region, it was reported that *Bt* hybrids performed better (Table 2) than non *Bt* *hirsutum* hybrid and *arboreum* variety in all situations (Bhatade *et al.,* 2006).

Better performance of *Bt* hybrids, MECH 184, MECH 162 and MECH 12 was noticed compared to non *Bt* hybrids in medium deep than shallow soil (Jagvir Singh *et al.,* 2004) with a higher harvest index of MECH 184 *Bt* (46.5per cent) and (51.5per cent) on shallow and deep soil respectively than MECH 184 non *Bt* (Table 3).

Sankaranarayanan and Nalayini (2015) reported that, *Bt* hybrids (1691 kg/ ha) produced higher seed cotton yield than non-*Bt* hybrids (1092 kg/ ha), while the controlled variety (LRA 5166) performed the average of these two (1399 kg/ ha).

Method of planting : In accordance with conditions laid down in the Genetic Engineering Approval Committee (GEAC) *Bt* cotton should be planted in the centre of the plot surrounded by non-*Bt* isogenic lines at the border in five rows for every acre of planting area. The size of refuge (the non *Bt* belt surrounded by *Bt*) should take at least five rows of non *Bt* or 20per cent of the total land sown, whichever is more . To meet the requirement of non *Bt* refuge (corresponding non *Bt* or non *Bt* of equivalent fibre quality) , seeds are provided with *Bt* seeds (450g of *Bt* + 120 g of non *Bt*).

For yield miaximization, following of proper seed rate and spacing are essential. Depending upon the hybrids and soil fertility, spacing varies, which ultimately decide seed rate of the hybrid. In sowing of *Bt* cotton, single seed is dibbled at a depth of 3 cm in the furrows, where fertilizers and insecticides are applied under irrigated condition. However, planting of single seed with pulses/castor/sunhemp seed facilitate the germination of cotton vigorously and later the extra plant is to be clipped to avoid root injury of cotton seedlings . In the Yellow River valley, China, transplanted *Bt* hybrid cotton yielded 31per cent more than the direct seeded cotton (Dong *et al.,* 2005). Leaf reddening in transplanted *Bt* cotton (20-25 days old) was reduced (7.8 to 9.2per cent) compared to dibbled cotton (19per cent).

Time of sowing : Optimum time of sowing is varying depends upon the climate, hybrids, rainfed and irrigated condition across the country. Sowing of conventional cotton beyond the recommended dates of planting invites the incidence of pests especially bollworms complex in many parts of the country, besides exposing the crop to unfavourable climatic conditions during crop maturity phase. As the *Bt* cotton is effective against bollworm complex and shows early maturity, delay in sowing of *Bt* cotton may not much aggravate the bollworm incidences or predispose them to unfavourable climatic conditions and thereby ensuring normal yields. The experiment on time of sowing of *Bt* hybrids conducted in different centres of AICCIP project revealed that *Bt* cotton following of the timely sowing recorded 1693 kg/ ha as compared to delay in sowing of 1389 kg/ ha at Surat, whereas delayed sowing increased the seed cotton yield in *Bt* cotton hybrids and at the same time reduced in non *Bt* hybrids. Prakash *et al.,* (2008) observed that a 10 day delay in sowing time (from the optimum date of 12 August) had no effect on seed cotton yield of Bunny *Bt* and RCH 2 *Bt* in the winter irrigated tract of southern zone. In contrary to that reports from All India Coordinated Cotton Improvement Project (AICCIP) indicate that a 20 day delay in sowing caused a reduction in the yield of *Bt* cotton by 18per cent at Surat, Gujarat and 22per cent at Khandwa, Madhya Pradesh (Singh *et al.,* 2008) and 31per cent at Dharwar, Karnataka (AICCIP, 2009).

Plant Population : The success in increasing the *Bt* cotton productivity depends on adoption of improved agro techniques. Plant population (spacing) contribute higher towards maximizing the yield. Optimum plant density is depending on the inherent vegetative habit of variety/hybrid and conditions of soil fertility, moisture and cultural practices (Bapna *et al.,* 1976). Similarly, optimum row spacing have a bearing on seed cotton yield. An yield of 2300 kg/ha was observed at Coimbatore, Tamil Nadu with closer planting at 75 x 60 cm (22,222 plants/ ha) (Sankaranarayanan *et al.,* 2011a). Narrow spacing of 67.5 x 60 cm recorded significantly higher seed cotton yield over wider spacing (100 x 60 cm) in canal command areas of northwestern Rajasthan (Nehra *et al.,* 2004). Raghuramireddy *et al.,* (2007) reported that under 90 cm row spacing, closer intra-row spacing of 30 cm (3111kg/ha) and 60 cm (3019 kg/ha) significantly enhanced seed cotton yield over 90 cm (2761 kg/ha). The highest seed cotton yield of RCH-134 *Bt* cotton hybrid was recorded at 67.5 x 90 cm spacing by Butter and Singh (2006) at Bhatinda. Vishwanath (2007) recorded significantly higher seed cotton yield with 90 x 30 cm spacing (2479 kg /ha) as compared to control (2139 kg /ha). The highest seed cotton yield recorded at 90 x 45 cm spacing for RCH-2 *Bt* cotton under rainfed conditions as reported by Bhalerao et al (2010). MECH 162 and RCH 2 *Bt* hybrids adopted at a spacing of 90x60 cm had recorded significantly higher seed cotton yield as recorded by Kalaichelvi(2009). Aruna and Sahadeva Reddy (2009) confirmed that planting *Bt* cotton at 90 cm x 45 cm gave higher kapas yield in scarce rain fall zone of Andra Pradesh. Manjunatha *et al.,* (2010) reported spacing of 60 x 30 cm recorded significantly higher (21.11 q / ha) seed cotton yield than wider spacing of 90 x 60 cm (15.59q /ha), 75 x 30 cm (18.85 q /ha) . The plant geometry of 120 cm × 45 cm recorded highest seed cotton yield (26.46 q/ha) and stood significantly superior over other planting geometries. It has 8.9 and 13.5per cent yield increment over 90 cm × 60 cm and 180 cm × 30 cm, respectively(Dadgale et al 2014).

The above said experimental results on spacing requirement of *Bt* hybrids may be generalized that *Bt* hybrids plant occupies less space because of compact growth in habit. The compact growth of *Bt* hybrids is provided opportunity to keep more population per unit area as compared to non *Bt* to reach optimum and higher plant population per unit area ultimately result in yield increase.

Nutrient management : Fertilizer is the foremost input, towards yield maximization. Application of 150 per cent of RDF (135: 67.5:67.5 NPK (on par with 125 per cent RDF) showed significantly higher number of bolls, single plant yield, and seed cotton yield (Sankaranarayanan, *et al.,* 2011a) . Significant differences were not observed in seed cotton yield in the first picking but in the second picking, 125 per cent of recommended dose of fertilizer (RDF) resulted in significantly higher yield as compared to 100 per cent RDF (Jagvir *et al.,* 2000). Vishwanath (2007) recorded significantly higher seed cotton yield 150 per cent RDF (2420 kg /ha) as compared to control (2139 kg /ha). MECH 162 and RCH 2 *Bt* hybrids applied with fertilizer levels of 160:80:80 kg of N, P and K/ha had recorded significantly higher seed cotton yield as compared to recommended level of 120:60:60 kg of N,PandK/ha (Kalaichelvi, 2009). Hallikeri *et al.,* (2011) indicated that increasing level of nitrogen from 80 to 120 and further to 160 kg/ ha significantly increased seed cotton yield by 12 and 19per cent,respectively. In contrary to that of higher fertilizer requirement and response of *Bt* hybrids observed in many field trials, non significant differences of seed cotton yield observed under different fertility levels by Raghuramireddy *et al.,*(2007). *Bt* hybrids performed better than conventional hybrids and required same quantity of fertilizer as observed by Hallikeri *et al.,*(2004).

Rajendran *et al.,* (2009) found that application of 150 per cent RDF combined with TNAU MN mixture recorded 26 per cent higher seed cotton yield in *Bt* cotton. On vertic Ustropepts of Coimbatore, Bandhopadhyay *et al.,* (2009) observed 60 kg N/ha as optimum dose for high yield and was adequate for conventional hybrids But *Bt* cottons are slightly more responsive to N application . Moreover, *Bt* cotton had a higher N content than non-*Bt* cotton suggesting that they may have a greater N uptake and metabolism than non-*Bt* cotton (Showalter *et al.,* 2009). Nehra and Yadav (2011) concluded that 108 X 60 cm spacing with application of 100per cent RDF (150 kg N and 40 kg P2O5 /ha) seems to be the optimum dose for RCH 134 *Bt* cotton hybrid in Canal command area of North-west Rajasthan.Late application of N and K fertilizer delay the senescence, (Dong *et al.,* 2005) . Hosmath et al (2014) Foliar application of KNO3 2per cent, soil and foliar application of MgSO4 @ 25 kg/ha and 1per cent respectively, and soil application of MgSO4 @ 25 kg/ha alone increased the seed-cotton yield by 25.0, 24.4 and 24.3per cent respectively, over the RDF. The yield of *Bt* hybrids (MCEH 184 and RCH 2) was higher than non-*Bt* NCS 145 and among *Bt* hybrids, the medium duration RCH 32 *Bt* was superior to short-duration MECH 184 under normal sowing date (Venugopalan et al,2012). *Bt* protein had some inhibitory effects on alkaline phosphatase activity in the rhizosphere soil, and it might promote dehydrogenase activity during the blooming period. However, it had no significant influence on protease, urease, or sucrose activities.and had no significant impact on the contents of organic matter, total nitrogen, available nitrogen, or potassium in rhizosphere soil. It could significantly decrease the content of available phosphorus during the flowering period(Wude yang et al (2012) .

Use of organic inputs is a long term remedy in order to get rid of any adverse effect of intensive agricultural system and to restore the soil health and environment. Performance of *Bt* hybrids under different organics revealed that cotton yield (kg/ha) was significantly higher in *Bt* (1172) over DHH-11 (876) and non *Bt* (719). *Bt* cotton hybrids had not influenced significantly on soil pH, EC, available N,P and K status in comparison to non *Bt* and locally adopted genotypes (Sankaranarayanan *et al.,* 2008).The similar results were reported by Hosmath *et al.,*(2004a) except for less availability of nitrogen (Table 4). Blaise (2011) reported that N100, GM + N100 and GM + N80 (1687–1734 kg/ ha) did not differ and were significantly better than the GM + N60 (1303 kg/ ha).

Water management : Water requirement of *Bt* cotton hybrids ranges from 60 to 120 cm in different regions. Early maturity character induced by *Bt* possibly leads to a reduced water requirement for *Bt* hybrid and the reduction may be equal to saving of one irrigation. Water requirement of *Bt* cotton at Coimbatore under drip irrigation was 764.8 mm, while in furrow irrigation was 917.2 mm, resulted a water saving of 16.6per cent. Whereas the water requirement of Non *Bt* cotton under drip irrigation was 789.8 mm (6.75per cent) compared to furrow irrigation (967.2 mm) with a water saving of 18.3per cent.The Water Use Efficiency (WUE) in *Bt* Cotton and Non *Bt* Cotton under drip irrigation with fertigation with water soluble fertilizer (WSF) at 100per cent RDF was 4.83 kg /ha mm (64.8per cent increase) and 3.76 kg /ha mm (57.9per cent increase) respectively over furrow irrigation (Asokaraja et al .,2011). Drip fertigation with WSF (drip at 125per cent WRc + fertigation at 100per cent RDF) has recorded higher yield of 39.6 q /ha (47.34per cent higher over control) in *Bt* cotton. Drip fertigation with conventional fertilizer (CF) has recorded 33.1 q /ha (23.24per cent increase over control). In case of Non *Bt* Cotton, the seed cotton yield under drip fertigation with WSF (100per cent dose) was 31.04 q /ha, which was 42.19per cent higher over control and 20.79per cent higher over fertigation with CF (Gokila *et al.,*2011). The yield of *Bt* cotton under drip fertigation with water soluble fertilizer (WSF) at 100per cent dose was 39.6 q /ha which is 27.64per cent increase over non *Bt* cotton (Muthukrishnan *et al.,* 2011). *Bt* cotton sown under irrigated condition (irrigation applied at three critical growth stages of cotton) significantly improved the seed cotton yield (33.71 q/ha) over rainfed condition (15.00 q/ ha) (Dadgale et al 2014) . The studies proved that *Bt* cotton is more efficient in term of water used.

Table 4. Yield, soil properties and available nutrient status in *Bt* and non *Bt* hybrids

Parameters	*Bt*	Non *Bt*	DHH 11	S.E	C.D(0.05)
Seed cotton yield (Kg/ha)cotton yield	1172	719	876	27.0	106
Organic carbon (%)	0.66	0.67	0.65	0.02	NS
EC(dS/m)	0.27	0.28	0.27	0.01	NS
pH	7.94	7.98	7.98	0.13	NS
Nitrogen (Kg/ha)	276.7	214.3	280.9	7.12	27.9
Phosphorus (Kg/ha)	21.4	20.4	20.82	0.6	NS
Potassium (Kq/ha)	333.5	330.7	329.8	1.94	NS

Hosmath et al., (2004a)

Weed management : *Bt* technology may favor development of super weed by gene transfer to wild relative species. Out crossing of transgenic to wild or weedy crop relatives has become one of the most debated environmental concerns related to transgenic plants. In India, cotton has only one close weed relative, *Gossypium stocksii*, found at northern Gujarat where cotton is not cultivated (Manjunath, 2007

). Pollen dispersal from transgenic cotton is also low. Further, the cotton pollen is heavy and cannot move beyond a few meters away from cotton fields. Therefore, currently the possibility of gene transfer and the development of super weed is a remote possibility. Even in other countries and with other *Bt* crops there is no evidence that super weeds have even developed over the past decade (Manjunath,2007). Pendimethalin @ 1.0 kg /ha followed by a hoeing at Faridkot (Punjab), pendimethalin or prometryn @ 1.5 kg/ha at Sriganganagar (Rajasthan), pendimethalin or trifluralin @ 1.5 kg/ha as pre-plant along with one hand weeding (HW) at 35 DAS for controlling *Trianthema* spp at Sriganganagar (Rajasthan), Galaxy 45 EC @ 2 l/ ha (a ready mix of clomazone @15 per cent w/w + pendimethalin @30 per cent w/w) along with one HW and two intercultural operations with *dora* / *kulpa* at Indore (M.P.) and hand weeding alone at Khandwa (M.P.) and Rahuri (Maharastra) were optimum for higher yield and net return (AICCIP, 2004).

In south, fluchloralin as pre-plant incorporation @ 1 kg/ha along with an interculture and HW at 25 DAS or two HW at 25 and 50 DAS under Lam, Guntur condition, HW or diuron @ 1-1.25 kg/ha along with HW at 30 DAS at Dharward, and two HW at 25 and 50 DAS or pendimthalin or fluchloralin @ 1.5 kg/ha along with two intercultural operations at 30 and 45 DAS at Raichur (KTK) are optimum. At Coimbatore (T.N.), HW twice at 20 and 40 DAS and galaxy @ 2 l/ha or fluchloralin @ 1 kg/ha as pre-emergence are effective (AICCIP, 2004).Pendimethalin @ 1.0 kg /ha as pre-emergence + two hand weeding at 30 and 60 DAS is effective, efficient and economical to control weeds in *Bt* cotton (Usdadia *et al.,* 20011). The highest weed control efficiency and BCR (2.37) were recorded by using the mixture of glyphosate 1kg /ha and pendimethalin 1kg /ha under Stale Seed Bed Technique followed by one hand weeding at 35 to 40 days after sowing in *Bt* cotton (Narayana *et al.,* 2011)

Cropping system

Inter cropping : Cotton is widely spaced, and slow growing in the initial stages for a relatively longer duration offers a vast scope for raising suitable intercrops. When compared to conventional cotton, *Bt* cotton can alter the pest population of cotton ecosystem.This situation warrants the retesting of recommended intercrops of cotton to find out their suitability. *Bt* cotton and *bhendi* intercropping registered the maximum seed cotton equivalent yield (4450 kg/ha) and land equivalent ratio (2.76) (Sankaranarayanan *et al.,* 2004). Relay cropping of *Bt* cotton with *rabi* sorghum, bengal gram, safflower, sunflower, linseed, lentil, peas could not produce any economic yields. But relay with hybrid castor followed by sunflower planted at 45 x 22.5 cm during fag end of September is successful. *Bt* cotton based innovative intercropping systems were evaluated at Nagpur and found that feasibility and profitability of intercropping of green leafy vegetables, cow pea, radish and cluster bean with *Bt* cotton recorded the mean seed cotton yields were 16,19,18,and 17.3 qt /ha, net profits of Rs. 20,000, 37,000, 42,000, 43,000 and benefit cost ratio of 1.97, 2.95, 4.43 and 5.57 respectively. Angrej Singh and Thakar Singh (2015) reported that maximum seed cotton equivalent yield recorded under *Bt* cotton + fodder maize intercropping system (2.61 t/ha) was 10.6, 17.6, 27.3 and 39.6per cent higher than *Bt* cotton + fodder cowpea, *Bt* cotton + summer mungbean, *Bt* cotton + long melon and *Bt* cotton + fodder pearlmillet, respectively. Raman Jeet Singh, and Ahlawat(2014) suggested that inclusion of legume and organic manure in transgenic *Bt*-cotton–wheat system is a sustainable practice for combating escalating prices of N fertilizers with environmental issues and instability of transgenic hybrids in south Asian countries.

Multi tier cropping : *Bt* cotton based multi tier vegetables intercropping system was developed at CICR, Coimbatore. In three tier system the highest seed cotton equivalent yield (43.5 q/ha) was registered with multi-tier system of cotton + radish+ amaranthus, where intercrops were planted between cotton rows, which was 99per cent higher than that in sole cotton (21.9 q/ha) and also registered the highest gross return (Rs.84,908/ha.) and net return (Rs.55,832/ha.) and benefit cost ratio (2.9) (Sankaranarayanan *et al.,*2008). Multi tier (three intercrops) vegetables intercropping of cotton +radish + cluster bean+ beet root system produced as much as seed cotton yield (25.45 q / ha) as compared to sole cotton (26.15 q /ha) in addition to vegetable yield of radish (6660 kg / ha) , cluster bean (4536 (kg /ha) and beet root (5671 (kg /ha) . Multi tier system was calculated the highest relative production and economic efficiency and land equivalent ratio of 182.2per cent, 308.7 per cent and 2.2 respectively as compared to sole cotton.

Refuge crop : Cultivation of refuge crop is mandatory for cultivation of *Bt* cotton.Insect resistance management is very important to conserve the *Bt* technology for long term benefits and therefore, refuge crop system is advocated. Non *Bt* cotton refuge is practiced in other countries like USA, and Australia and have also been recommended by Govt. of India. The refuge crop could be 20 per cent of the *Bt* cotton with the intervention of plant protection measures, when required or 5 per cent of the area without providing any chemical protection. As a partial modification of this regulatory requirement, the GEAC has now permitted planting strip crop of pigeonpea as a refugia. Thus strip cropping of cotton + pigeonpea, a widely adopted system in Central India (Blaise *et al.,* 2005) will continue even with *Bt* hybrids. Isbell (2000) reported that net loss in return due to the 30 per cent refuge is US$ 29.8/ha. In Argentina alternate host crops, such as corn, soybean and sorghum, which provide an additional non *Bt* refuge (ICAC,2007). The Environment protection Agency (EPA) of USA has approved a natural refuge for Bollgard II, if planted in the states east of Texas. However, natural refuge is not allowed wherever pink boll worm *(Pectinophora gossypiella)* is a major pest, because alternate host crops and plants do not produce a large enough susceptible population (ICAC, 2007). Planting of *Bt* cotton in 80 per cent of area and allotting of remaining 20 per cent area to marigold/okra-chickpea is recommended as alternate strategy for refuge (non *Bt* cotton) by UAS,Dharwad (Anonymuos,2008a).

Sequential cropping : *Bt* cotton hybrids matured earlier by 15 to 30 days than local checks. This advantage with *Bt* cotton can be exploited for making timely sowing of succeeding rabi crop (e.g. wheat, mustard and maize) in cotton based cropping system of North and Central zone and timely planting of kharif rice crop in rice fallow cotton tract of South Zone. Early maturity induced by *Bt* technique, restricting the completion of *Bt* cotton harvest before December, which favored for double cropping in certain regions. The cropping system is shifted from monocropping to *Bt* cotton- Maize in Andhra Pradesh and *Bt* cotton- wheat/ Summer ground nut in Maharashtra and

Gujarat states. However, there is no shift is observed in existing Soybean- hybrid cotton + pigeon pea system of Central India. Nalayini *et al.,* (2009) found that poly-mulched cotton-maize system recorded the highest net return (Rs 74,178/ha) and benefit cost ratio (1.68) as against the conventional system (Rs 29,863 and 1.04).In the north zone, even with *Bt* hybrids, cotton-wheat system remained more efficient and profitable than either cotton-barley or cotton-mustard systems (TMC, 2008).

Cotton-wheat : The determinate nature of *Bt* cotton enables timely sowing of wheat leading to greater system productivity of this most widely practiced cropping system (1.5 m ha) of north-west plains zone. Early sowing of wheat (8th Nov.) gave significantly more grain yield (41.22 q/ha) than the late sowing (20th Dec.) (37.58 q/ha) (Shirpurkar *et al.,* 2008). The grain yields of wheat decreased with each day delay in sowing might be because of shorter period available for anthesis and grain development. Reduction in wheat yield due to late sowing has also been reported by Sardana *et al.,* (2002).The adoption of *Bt* technology increased the average productivity of cotton from 300 to 558 kg lint/ha in the cotton-wheat production zone. Gangaiah, and . Ahlawat (2014) reported that two *Bt* cotton hybrids did not markedly alter the performance of succeeding wheat. However,the system productivity (cotton-equivalent yield, CEY) of *Bt* cotton–wheat was 24.2per cent (4.72 tonnes/ha) higher than the non-*Bt* cotton–wheat system (3.80 tonnes/ha).

Fibre quality : Besides yield improvement, quality of cotton fibre is the other important component that has a bearing in any cotton research programme. Jenkins *et al.,* (1991) in the first field test of transgenic cotton lines reported that yield and fibre properties were in the range of the adapted cultivar Similarly, Ethridge and Hequet, 2000 could not find differences in micronaire, uniformity ratio, strength and elongation measured in High Volume Instrument as a result of transgenic technology. The quality parameters viz., 2.5per cent span length, maturity ratio, uniformity ratio, micronaire, fibre elongation and fibre quality Index were not different in hybrids or *Bt* versus non-*Bt* (Sankaranarayanan *et al.,* 2008). None of the physical and quality parameters differed with NCS 145 *Bt* and NCS 145 hybrid

Table 5. Seed cotton yield (kg/ha) and quality parameters in *Bt* and non *Bt* hybrids

Parameters	Yield span (kg/ha)	2.5 per cent length (mm)	Uni formity-ratio	Micro-naire value	Maturity (%)	Strength (g/tex)	Elong-ation (%)
MECH 184 *Bt*	2183	29.13	46.33	3.85	66.93	24.17	5.58
MECH 184 non *Bt*	715	29.3	45.83	3.72	65.48	23.07	5.60
MECH 162 *Bt*	1912	25.16	47.83	3.67	66.17	19.18	5.87
MECH 162non *Bt*	1077	24.50	48.50	3.82	66.43	18.75	5.83
MECH 12 *Bt*	1935	27.53	48.17	3.53	65.07	23.95	5.13
MECH 12 non *Bt*	634	27.95	48.17	3.68	65.77	22.97	5.67
SEM +	193.5	0.41	0.41	0.09	0.80	0.60	0.11
CD at (p=0.05)	647	1.38	1.36	NS	NS	20.2	0.34

Hallikeri *et al.,* (2004)

under rainfed conditions in vertisols at LAM, Guntur (Bharathi *et al.,* 2011).Performance trial conducted at Dharwad (Table 6) under protective irrigated condition (Hallikeri *et al.,* 2004) revealed that quality parameters were not influenced by *Bt* gene. Ginning percentage and halo length, *Bt* cotton hybrids expressed better performance which was on par with their respective non-*Bt* hybrids (Ansingkar *et al.,* 2005). There was no difference among micronaire, 2.5per cent span length, immature fibre content, neps/g and maturity ratio at the final stage of fibre development. However, the tenacity encountered some change in the final stage of fibre development (Yadav et al, 2012).

Contrary to the general trend, Mayee *et al.,* (2004) reported that *Bt* hybrids exhibited higher ginning percentage over their non *Bt* counterparts. For lint index, greater differences were observed between *Bt* and non *Bt* hybrids. *Bt* hybrids exhibited slightly lesser 2.5 per cent length than their non -*Bt* hybrids. This is possibly due to the shortening in the crop duration. However, these differences noted are not of much consequence as they were in the acceptable range. In general, the assessment of fibre quality parameters of *Bt* cotton hybrid indicate that the fibre properties of *Bt* cotton hybrids were in the range of the adapted cultivar with few exceptions.

CONCLUSION

Blaise et al (2014) reported *Bt* cotton that besides providing resistance against lepidopteron pests, the *Bt*. hybrids matured earlier, were more determinate, had a rapid leaf area development, retained more early set fruiting forms. Some prominent changes accompanying this technology have been, compulsory seed treatment with imidachloprid, advancement in sowing wherever supplemental irrigation was available, a delay in sowing in the traditional rainfed till the soil profile absorbs sufficient moisture, application of atleast 25per cent higher fertilizer dose, shift towards balanced fertilization, foliar application of K and micronutrient mixtures. Adoption of drip irrigation and fertigation, more widespread use of booth pre-emergence (pendimethalin) and post-emergence herbicides (quizalofop ethyl and pyrithiobac sodium) practice of stale seed bed technique for weed management, pruning and extension of crop duration are some other agro techniques which are being adopted by *Bt* cotton farmers.

The steep increase in adoption of *Bt* hybrids across the country by numerous farmers have proved that the technology is well accepted by Indian farmers. Around 95per cent of the cotton area is now under *Bt* hybrids and this acreage has perhaps saturated. Over the last few years despite increase in area under *Bt* hybrids the productivity at national level has not improved. The morphological and physiological changes in these introgressed *Bt* cultivars offer an excellent opportunity for agronomic manipulation. Hence, further improvement in the productivity of cotton and cotton based production systems can only be expected by fine tuning its agronomic practices. Several opportunities for enhancing yields with *Bt* cotton have been documented. Adoption of these technologies may help to improve *Bt* cotton yields.

REFERENCES

AICCIP, 2004. Annual report of All India Coordinated Cotton Improvement Project. Central Institute for Cotton Research, Coimbatore. 2003-04.

AICCIP, 2009. Annual Report of All India Coordinated Cotton Improvement Project, Central Institute for Cotton Research Coimbatore, 2008-09.

Altman, D.W., D.M. Stelly and D.M. Mitten.1991. Quantitative trait variation in phenotypically normal regenerants of cotton. *In Vitro Cell Development Biology* **27:** 132-38.

Anand, S.R., Ramesh Babu, P. Ashoka and R. Smitha. 2008. Studies on yield, economics and bollworm incidence of *Bt* cotton (*Gossypium spp.)* hybrids as influenced by different plant spacings. *Crop Res.* **36 :** 120-24.

Angrej Singh and Thakar Singh 2015. Growth, yield and quality of *Bt* cotton (*Gossypium hirsutum*) as influenced by different intercropping systems and nitrogen levels *Indian Journal of Agronomy* **60 :** 236-44

Anonymous. 2008a. Annual report of Central Institute for Cotton research, Nagpur 2001-2002,

Anonymous, 2002. *Final report of National Trial on Evaluation of Bt cotton hybrids*, ICAR, New Delhi, 2002

Ansingkar, A.S., S.S., More, S.S., Bhatade, M. Dhuppe and L.M. Choudhary. 2005. Evaluation of transgenic *Bt* cotton hybrids in comparison with non- *Bt* and checks in rainfed condition. Journal of Soils and Crops. **15 :** 338-42.

Aruna, E .2011. Effect of time of application of nitrogen and potassium on growth and yield of *Bt* cotton. Abstract (In) Published in World Cotton Research Conference -5, Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.156

Aruna, E and B.S. Reddy. 2009. Response of *Bt* cotton to plant geometry and nutrient combinations. *Indian J. Agricultural Res..* **43** : 206-10.

Asokaraja,N., P. Muthukrishnan and J. Gokila .2011. Standardizing water and fertilizer requirement of *Bt* cotton hybrid (mallika) under drip fertigation system. Abstract (In) Published in World Cotton Research Conference -5, Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.33

Bandhopadhyay, K.K., A.H. Prakash, K. Sankarnarayanan, B. Dharajyothi and N. Gopalkrishnan. 2009. Effect of irrigation and nitrogen on soil water dynamics, productivity and input use efficiency of *Bt* cotton in Vertic Ustropept. *Indian J. Agric. Sci.* **79:** 448–53.

Bange, P.M., J.S. Caton and P.S. Milroy. 2008. Managing yields of high fruit retention in transgenic cotton *(Gossypium hirsutum* L.) using sowing date. *Aust. J. Agric. Res.* **59 :** 733–41.

Bhalerao, P.D., P.P. Gawande, P.U. Ghatol and B.R. Patil. 2008. Performance of *Bt* cotton hybrids for various spacing under rainfed condition. *Agric. Sci. Digest.* **28 :** 54-56.

Bharathi,S., S. Ratna Kumari and V. Chenga Reddy. 2011. Productivity of *Bt* cotton as influenced by plant geometry and nutrient management under rainfed conditions in vertisols. Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.149

Blaise, D. 2011. Tillage and green manure effects on *Bt* transgenic cotton (*Gossypium hirsutum* L.) hybrid grown on rainfed vertisols of central India. *Soil Tillage Res.* **114:** 86-96 .

Blaise, D., G. Majumdar and K.U. Tekale. 2005. On-farm evaluation of fertilizer application and conservation tillage on productivity of cotton + pigeon pea strip intercropping on rainfed Vertisols of central India. *Soil Tillage Res.* **84:** 108–17.

Blaise,D, M.V. Venugopalan and A.R. Raju 2014. Introduction of *Bt* cotton hybrids in India: Did it change the agronomy? *Indian Journal of Agronomy* **59 :** 1-20

Chen, Dehua., Ye, Guoyou., Yang, Changquin., Chen, Yuan. and Wu, Yunkang. 2004. Effect after introducing *Bacillus thruingiensis* gene on nitrogen metabolism in cotton. *Field Crop Research* **87 :** 235-44.

Clive J. 2014. Global Status of Commercialized Biotech/GM Crops: 2014. ISAAA Brief No. 44. ISAAA: Ithaca, New York

Dadgale, P R, D A Chavan, B A Gudade, S G Jadhav, V A Deshmukh and Suresh pal 2014. Productivity and quality of *Bt* cotton (*Gossypium hirsutum*) as influenced by planting geometry and nitrogen levels under irrigated and rainfed conditions. *Indian Journal of Agricultural Sciences* **84 :** 1069–72.

Dason, A.A., S. Krishnasamy, Y.S. Ramakrishnan and D. Krishnadoss. 1996. Cotton growing environment Book published from Agricultural Research station, Kovilpatty-628 501 Tamil Nadu agricultural University, Coimbatore, India.

Deosarkar, B., S.S. Bhatade and A.R. Gaikwad. 2004. Comparative performance of *Bt* cotton hybrids and their conventional version under rainfed conditions of Marathwada region. *J. Cotton Res. Dev.* **22 :** 150-52.

Dong, H., W. Li, Z. Li, W. Tang and D. Zhang. 2005. Evaluation of production systems in china that uses reduced plant densities and retention of vegetative branches. *J. Cotton Sci.* **9 :** 1-9.

Ethridge, M.D and E.F. Hequet. 2000. Fiber properties and textile performance of transgenic cotton versus parent varieties. *In*: *Proceedings of the Beltwide Cotton conference, National Cotton Council* 1: pp. 488-94

Falconer, D.S. 1989. Introduction to quantitative genetics. 3rd ed. John Wiley and Sons. New York.

Fitt GP, Mares CL, liewelly BJ. 1994. Field evaluation and potential ecological impact of transgenic cotton (*G. hirsutum*) in Australia. *Bio control Sci. Tech.* **4 :** 535-48.

Flint HM, Henneberry TJ, Wilson FD, Holuguin E, Parks N, Buchler RD. 1995. The effect of transgenic cotton *G. hirsutum* containing *Bt* toxin gene for the control of pink bollworm and other arthropods. *South western Entomologist* **20 :** 281- 92.

Gangaiah, B and I.P.S. Ahlawat 2014. Nitrogen fertilization of *Bt* cotton (*Gossypium hirsutum*) wheat (*Triticum aestivum*) cropping system *Indian Journal Agronomy* **59 :** 235-41.

Gokila,J., P. Muthukrishnan, and N. Asokaraja .2011. Techno economic feasibility of drip fertigation system with water soluble and conventional fertilizers in *Bt* and non *Bt* cotton hybrid (mallika). Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.134

Hallikeri, S.S, H.L. Halemani, R.A. Nandagavi and S.S. Nooli. 2004. Response of Mahyco *Bt* cotton hybrids to levels of fertilizer under protective irrigation. pp. 139-141. *In: International Symposium on "Strategies for Sustainable Cotton Production-A global Vision"*during November 23-25, 2004 held at University of Agricultural Sciences, Dharwad, Karnataka.

Hallikeri, S.S., B.C. Patil, R.A. Nandagavi and R. Malik .2011. Pruning and detopping studies in *Bt* cotton . Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.54

Harries FA, Furz RE, Colboun Jr DS. 1996. Cotton insect management in transgenic *Bt* cotton in the Mississippi Delta, 1992- 95. In: Proceeding Beltwide cotton conferences, Naghville TN, USA, Jan 1996. Memphin USA: National cotton council, **2 :** 854-55.

Hebbar, K.B., M.R.K. Rao and B.M. Khadi. 2007. Synchronized boll development of *Bt* cotton hybrids and their physiological consequences. *Curr. Sci.* **93 :** 693–95.

Hosmath, J.A. D.P. Biradar, V.C. Patil, Y.B. Palled and L.H. Malligawad 2014. Nutrient requirement of *Bt*. cotton (*Gossypium hirsutum*) *Ind. Jour. Agro.* **59 :** 133-38

Hosmath, J.A., Biradar, D.P., Deshpande, S.K., Dodamani, S.V., Rizwan Haris, M.D. and Nooli, S.S. 2004. Study of *Bt* and non-*Bt* cotton performance in organics and its effect on soil properties and nutrient status. In *International Symposium on "Strategies for Sustainable Cotton Production-A Global Vision* during November 23-25,2004 held at University of Agricultural Sciences, Dharwad, Karnataka, pp. 135-38.

ICAC. Recorder. 2007. Refuge requirements and their implications in Biotech cotton. Technical information section Vol xxv No. 3, Sep 2007, p. 14-18.

Isbell, Hollis. 2000. Comments of the National cotton council on *Bt* resistance management and benefits of Bollgard cotton, available at http:// www.cotton.org/issues/2000/*Bt*-reistance.cfm

Jagvir singh, Venugopal, M.V. and. Kairon, M.S. 2000. Effect of cotton based cropping systems and nutrient management in the productivity and soil fertility of rainfed vertisols. Extended summaries. *International conference on Managing Natural Resources*. February 14-18, 2000, New Delhi, India Vol.3, pp.945-946.

Jagvir Singh., Rao, M.R.K., Mohan Punit and Mayee, C.D. 2004. Impact of soil depth on yield of *Bt* cotton hybrids under rainfed conditions. *Jour. Cotton Res. Dev.,* **20**:80-82.

Jenkins, J.N., W.L. Parrott, Jr. J.C. McCarty, K.A. Barton and P.F. Umbeck. 1991. Field test of transgenic cottons containing a *Bacillus thuringiensis* gene. Missisipi Agricultural Experimental Station Bulletin 174.

Kalaichelvi, K. 2009. *Bt* cotton response to plant geometry and fertilizer levels. *J. Cotton Res. Dev.* **23** : 96-99.

Keeling, J.W., C.G. Henninger and Abernathy. 1993. Effects of DPXPE 350 on Cotton (*Goyssypium hirsutum*) growth, yield and fibre quality. Weed Technol. **74 :** 930-33.

Kranthi KR, Jadhau DR, Kranthi S, Wanjari RR, Ali S, Russel D. 2002. Insecticide resistance in five major insect pest of cotton in India.*Crop Prot.* **21 :** 449-60

Mandal, D.K., C. Mandal and M.V. Venugoplan. 2005. Suitability of cotton cultivation in swell-shrink soils in central India. *Agric. Sys.* **84 :** 55–75.

Manjunath, S. and Y.C. Panchal.1989. Growth and yield components of cotton as influenced by herbicides. *J. Maharashtra Agricultural University.* **14 :** 181-83.

Manjunath, T.M.2007. *Q and A on Bt cotton in India.* Answer to more than 70 question on all aspects. Published by All India Crop Biotechnology Association, New Delhi, India p.78.

Manjunatha, M.J., A.S. Halepyati, B.G. Koppalkar and B.T. Pujari. 2010. Influence of different plant densities on the growth, yield and economics of *Bt* cotton (*Gossypium hirsutum L.*) genotypes under dryland condition. *Karnataka J. Agric. Sci.* **23 :** 580-83

Mayee, C.D. and M.R.K. Rao. 2002. Likely impact of *Bt* cotton cultivation on production and utilization in India. *In*: Proc: *National Seminar on Bt cotton scenario with special references to India*, 23rd May 2002, UAS, Dharwad, Karnataka, pp. 51-57.

Mayee, C.D., P. Singh, P. Mohan and D.K. Agarwal. 2004. Evaluation of *Bt* transgenic intra-*hirsutum* hybrids for yield and fibre properties. *Indian J. Agric. Sci.* **74 :** 746-47.

Muthukrishnan, P., N. Asokaraja and J. Gokila .2011. Evaluation of drip fertigation system on growth and yield of *Bt* cotton and non-*Bt* cotton hybrid (mallika). Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.33

Nalayini, P., R. Anandham, K. Sankaranarayanan and T.P. Rajendran. 2009. Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum*) and maize (*Zea mays*) cropping system. *Indian J. Agron.* **54 :** 409-14

Narayana, E., S. Reddy and V. Rajeswari .2011. Stale seed bed technique of weed control for *Bt* cotton based intercropping system. Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.87

Nehra, P.I., K.C. Nehara and P.D. Kumawat. 2004. Performance of *Bt* cotton hybrids at different spacings in canal command area of North Western Rajasthan. *J. Cotton Res. Dev.* **18 :** 189-90.

Nehra, P.L and P.S. Yadav 2011. Agronomic evaluation of *Bt* cotton hybrid (RCH 134 *Bt*) under varied crop geometries and fertilizer levels in canal command area of north-west Rajasthan. Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.54

Prakash, A.H., K.K. Bandyopadyaya and N. Gopalkrishnan. 2008. Growth and biomass portioning in *Bt* vs non *Bt* cotton hybrids in winter irrigated situation in southern zone of India. *J. Indian Soc. Cotton Improvement.* 129–42.

Raghurami Reddy, P., M. Gopinath and L. Jalapathirao. 2007. Performance of genetically modified cotton at different fertility levels and plant geometry under irrigated condition. *Crop Res.* **34 :** 305-07.

Rajendren, K., Mohamed Amanullah, M. and Vaiyapuri, K.2009. Agronomic Performance of *Bt* and Non *Bt* Cotton hybrids *Madras Agric. J.,* **96 :** 378-79

Rekha, G.O. 2007. A Comparative Assessment of Morpho Physiolgical Characters and Yield in *Bt* and Non-*Bt* Cotton Hybrids Abstract published in Karnataka *J. Agric. Sci.* **20 :** 2007

Sachs, E.S., J.H. Benedict, D.M. Stelly, J.F. Taylor, D.W. Altman, S. A. Berberich and S.K. Davis. 1998. Expression and segregation of genes encoding Cry1A insecticidal proteins in cotton. *Crop Sci.* **38 :** 1-11.

Sankaranarayanan K and P. Nalayini 2015. Performance and behaviour of *Bt* cotton hybrids under sub-optimal rainfall situation Archives of Agronomy and Soil Science, 2015 Vol. 61, No. 8, 1179–1197, http://dx.doi.org/10.1080/03650340.2014.986112

Sankaranarayanan, K., C.S. Praharaj, K.K. Bandyopadhyay and N. Gopalakrishnan. 2008. Performance and behavior of *Bt* cotton hybrids under sub-optimum rainfall situation. Abstract published in *13th Vasantrao Naik Memorial National Agriculture Seminar on "Livelihood Security through Rainwater Management"* during January 22-23, 2008 held at College of Agriculture, Nagpur. p. 39.

Sankaranarayanan, K., C.S. Praharaj, P. Nalayini and N. Gopalakrishnan. 2011b. Evaluation of *Bt* (*Bacillus thuringiensis*) and non *Bt* cotton (*Gossypium hirsutum*) hybrids under varied planting time. *Indian J. Agron.* **56 :** 68-73.

Sankaranarayanan, K., C.S. Praharaj, P. Nalayini and N.Gopalakrishnan. 2011a. Growth, yield and quality of *Bt* cotton (*Gossypium hirsutum*) hybrid under varied planting pattern, NPK levels and seasonal variations. *Indian J. Agric. Sci.* **81 :** 871-74.

Sankaranarayanan, K., Praharaj, C.S., Nalayini, P.and.Dharajothi, B. 2004. Studies on intercropping in *Bt* cotton hybrid. *Abstract Published in the National Symposium on "Changing World order Cotton Research, Development and Policy in context*" on 10-12th August 2004, ANGRAU, Hyderabad, p.42.

Sardana, V., S.K. Sharma and Randhawa. A.S. 2002. Performance of wheat (*Triticum aestivum*) varieties under different sowing dates and nitrogen levels in the sub-montane region of Punjab. *Indian Journal Agronomy* **47 :** 372-77

Shinde, V.S., L.S. Deshmukh, S.A. Shinde and K.K. Zade. 2009. Influence of rainwater management through different agro techniques on yield, yield attributing characters and economics of cotton. *J. Cotton Res. Dev.* **23 :** 51–55.

Shirpurkar, G.N., Wagh, M.P. and Patil, D. T. 2008. Comparative performance of wheat genotypes under different sowing dates. *Agricultural Science Digest.* **28 :** 231-32

Showalter A.M., H. Shannon, E. T. Bruce and Y. Carriere. 2009. A primer for using transgenic insecticidal cotton in developing countries. J. Insect Sci. 6: pp. 39. Online: insectscience.org/9.22

Singh, J., D. Blaise, M.R.K. Rao, C.D. Mayee, and M.S. Deshmukh. 2003. Assessment of agronomic efficiency of *Bt* cotton in rainfed Vertisols. *J. Indian Soc. Cotton Improvement.* 185-90.

Singh, K., K. Singh, H.R. Garg and P. Rathore. 2006. Effect of nutrient on productivity of seed cotton yield and other availably parameters in American cotton. *J. Cotton Res. Dev.* **20 :** 216-18.

Sunitha, V., K. Chandrasekhar and R. Veeraraghavaiah. 2010. Performance of *Bt* cotton hybrids at different nitrogen levels *J. Cotton Res. Dev.* **24 :** 52-55

TMC. 2008. *Final Report of TMC MM 2*, Central Institute for Cotton Research, Regional Station, Coimbatore.

TMC. 2008. *Final Report of TMC MM 2*, Central Institute for Cotton Research, Regional Station, Coimbatore.

Usdadia,V., J.G. Patel, V.C. Raj, R.R. Parmar, R.L. Leva, C.M. Sutaria and V. Kumar .2011. Comparative efficiency and economic viability of herbicides for controlling weeds in *Bt* cotton (Gossypium hirsutum L.). Abstract (In) Published in World Cotton Research Conference -5 Theme: Technologies for Prosperity held during November 7-11 at The Renaissance Hotel and Convention Centre, Mumbai, India organized by International Cotton advisory Committee (ICAC), Washington, Dc in collaboration with Indian Society for Cotton Improvement (ISCI), Mumbai, India. P.89

Venugopalan, M V, Rachana deshmukh, K B Hebbar and N R Tandulkar 2012. Productivity and nitrogen-use efficiency yardsticks in conventional and *Bt* cotton hybrids on rainfed Vertisols. *Indian Journal of Agricultural Sciences* **82 :** 641–44.

Venugopalan, M. V., Challa, O., Ramamurthy, V. and Kalsarpe, S. 2004. Role of soil and climatic factors in modulating cotton fibre quality parameters. *In: Proedings of the International Symposium on Strategies for Sustainable Cotton Production-A Global Vision.* Crop Production (Vol-2), 23-25 Nov. 2004, UAS, Dharwad. pp.15-21.

Venugopalan, M.V., K. Sankaranarayanan, D. Blaise, P. Nalayini, C.S. Prahraj and B. Gangaiah. 2009. *Bt* cotton (*Gossypium* sp.) in India and its agronomic requirements - A review. *Indian J. Agron.* **54 :** 343-60.

Vishwanath. 2007. Response of Late Sown *Bt* Cotton (*Gossypium hirsutum* L.) to Plant Spacings, Fertilizer Levels and NAA Applications Under Irrigation. *Karnataka J. Agric. Sci.* **20.**

Wude yang, Meijun zhang, and Guangwei ding 2012). Effect of Transgenic *Bt* Cotton on Bioactivities and Nutrients in Rhizosphere Soil *Communications in Soil Science and Plant Analysis*, **43 :** 689–700.

Yadav, A, G F S Hussain and R P Nachane 2012. Comparative studies on the physical properties of fibres of *Bt* and non-*Bt* cottons at various stages of growth *Indian Journal of Agricultural Sciences* **82 :** 957–60

Yeledhalli, N.A., S.S. Prakash and M.V. Ravi. 2008. Productive Potential of Soils of Tungabhadra Project Area for *Bt* Cotton. *Karnataka J. Agric. Sci.* **21 :** 35–37.

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Characterization of a bioremediation bacterium from cotton fields of Gunupur area, Odisha

THADEPALLI VENU GOPAL RAO AND MANOJ KUMAR DAS

Mandava Institute of Engineering and Technology, Jaggayyapeta-521175

E-mail : gopalraovt@gmail.com

ABSTRACT : *Carbofuran* (2, 2-Dimethyl-2, 3-dihydro-1-benzofuran-7-yl methylcarbamate) is used as a broad spectrum pesticide (which is a systemic insecticide) to control the pests of many crops (like rice, *cotton,* maize, potatoes, pumpkins, sunflowers, pine seedlings and spinach etc,). The compoud gets degraded naturally in the environment. However, if the chemical persists in the soil, it is biomagnified and can cause health hazardous to plants and animals (*Carbofuran* is highly toxic to vertebrates with an oral lethal dose of 8–14 mg/kg in rats and 19 mg/kg in dogs, which were found to be a neurotoxic) including human populations.

We have undergone an experimental study on *Cabofuran* subjected cotton field of GUNUPUR 521175, Odisha by isolating a microbial strain from same cotton field which uses this insecticide as a source of Carbon and Nitrogen for growth. The characterization of the isolated microbe i.e., both the morphological and biochemical tests revealed that the bacterium found to be as *Bacillus brevis.* This bacterium degrades *Carbofuran* to Carbofuran phenol, which is relatively less toxic substance. In growth kinetic experimental analysis the degradation of *Cabofuran* by bacterium after 5 days (grown) culture was found to be 65.08 per cent. It is also suggested by "plasmid isolation experimental studies" that the basic mechanism of degradation capability of this bacterium is due to presence of a specific gene that is present mainly as extrachromosomal [(resistant gene in plasmid which helps in growth on the pesticide's carbon and nitrogen source].

A further experimental study, especially on the molecular biological characterization of the plasmid may help in developing certain specific strains of bacteria for the bioremediation of *Carbomate* group of pesticides *per se.*

A pesticide is a chemical or biological agent that deters, incapacitates, kills, or otherwise discourages pests. They are used in agriculture to control weeds, insect infestation and diseases (Beirne, 1975). Use of pesticide is tremendously increasing day by day in agriculture with an aim of more production. Carbofurans is a broad spectrum pesticide marketed under the trade name "Furadan", is used to control insects in a wide variety of crops including rice, cotton, potatoes etc. Its IUPAC name is 2, 3, dihydro-2, 2-dimethyl, 7-benzofuranyl methyl carbamate, molecular formula: $C_{12}H_{15}NO_3$ and molecular mass is 221.25.

It has been reported that over 98 per cent of sprayed insecticides and 95 per cent of herbicides reach a destination other than their target biotic species, including non-target abiotic species that are air, water and soil (Howard, 1996). Pesticides may cause acute and delayed health effects in people who are exposed. Pesticide use raises a number of environmental concerns. Thus, *in situ* removal, modification or detoxification pesticide is important for restoration of the environment. Bioremediation is a technique that involves the use of organisms to remove or neutralize pollutants from a contaminated site (Luck, 1981; Van der Hoek *et al*, 1998). The process uses naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances. Microorganisms are used to perform such kind of the function of 'bioremediation' are known as 'bioremediators' (Price, 1974). Many strains of microorganisms have been reported for bioremediation may degrade, transform or accumulate a huge range of compounds including hydrocarbons, poly chlorinated biphenyls (PCBS), poly aromatic hydrocarbons (PAHS), pharmaceutical substances, metals etc. (Flaherty and Wilson,1999). The present work is aimed at "isolation and characterization of carbofuran degrading microorganisms" that are isolated from soil. We have also addressed the rate of biodegradation by the isolated microorganism and attempt has also been made for the identification of bacterium gene responsible for the degradation of the carbofuran.

MATERIALS AND METHODS

1. Collection of soil *:* Ten soil samples were collected from B horizon layer from different cotton field located near Gunupur area, Odisha with sterile plastic bags and then brought to the Laboratory for analysis. The soil samples are dried under room temperature to remove excess amount of water present on the samples.

2. Isolation of the bacteria : The isolation of the carbofuran degrading bacteria at the laboratory was carried out by following serial dilution standard procedures (Aneja, 2002). There are three different culture media are prepared for isolation of the bacteria such as minimal medium (MM), Nitrogen free medium (NFM) and Nitrogen free medium with glucose (NFMG) (Cock, 1985).

3. Maintenance of bacteria at laboratory : It is necessary to maintain the bacterium culture at the laboratory for future purpose. Pure culture of the bacteria was maintained at the laboratory using the enriched medium showing maximum growth. The pure culture of bacterium was maintained by following standard slant culture method with little modifications (Singleton, 1999).

4. Characterization of microorganism : The isolated bacterium was characterized according to Bergey's Manual of Determinative Bacteriology (Holt *et al.*, 1994) with minor modifications. Further, the confirmation was with molecular test and the phylogenic analysis of the species was also made.

5. Determination of Growth curve of the bacterium : The pure culture of isolated bacterium is utilized for determination of growth curve. Optical density (OD) of the culture is recorded with the help of spectrophotometer at 600 nm at an interval of 30 minutes. The medium without bacterial inoculation was maintained as control.

6. Isolation of plasmid from the bacterium : Isolation and recovery of plasmid from the fresh culture of bacterium was carried out with alkaline lyses solutions (Sambrook *et al*, 2006).

7. Bioremediation experiments : The isolated bacterium and the carbofuran (TATA FURAN) which is commercially available are inoculated together in a conical flask and then kept in a rotary shaker. The rotary shaker is allowed for continuous agitation for ten days. The conversation of carbofuran to carbofuran-phenyl a less toxic substance are measured with the help of Thin layer chromatography (TLC) and

Gas chromatography and mass spectroscopy (GCMS) at the regular interval of inoculation. The suspension present in the mixed culture were analysed by Gas chromatography and Mass spectroscopy (GCMS). GC"MS (MSGC" 11) instrument with Capillary column of HP"3 (50 mm × 0.521mm, film thickness 0.25Am). 1 ml of extract was carefully injected into GC"MS for analysis. The chemical compositions were identified by comparing their retention indices (RI) and mass fragmentation pattern. The results obtained were recorded. The maximum days of inoculation (DOI) has been chosen after the constant value was obtained.

RESULTS AND DISCUSSION

The collected soil samples showed bacterial colonies in the culture medium at the land to laboratory experimentation. All the culture media used have developed the bacterial colonies. Table 1 represented the appearance of bacterial colonies in the different kinds of culture media. The numbers of colonies were ranged between 35 and 80 after 5 days of growth bacterial culture medium as specified (Table 1). The number of bacterial colonies were more in designed culture medium containing free of nitrogen source but with glucose as carbon source (80 in number), followed by designed culture medium with free of carbon containing 53 colonies in number. From the both the growth sources of the experiments on developments of the bacterium etc., are identified this microbe as *Bacillus sp.* Growth curve of isolated bacterium strain is established in the batch culture with the Hi-media nutrient broth (Fig. 1). As shown in Fig. 1 the bacterium showed regular sigmoid growth curve with lag phase up to 90 minutes, followed by log or exponential phase up to 250 minutes. After exponential phase the bacterium reached to stationary phase. The plasmid was isolated from the exponentially grown (mid log) culture and isolated

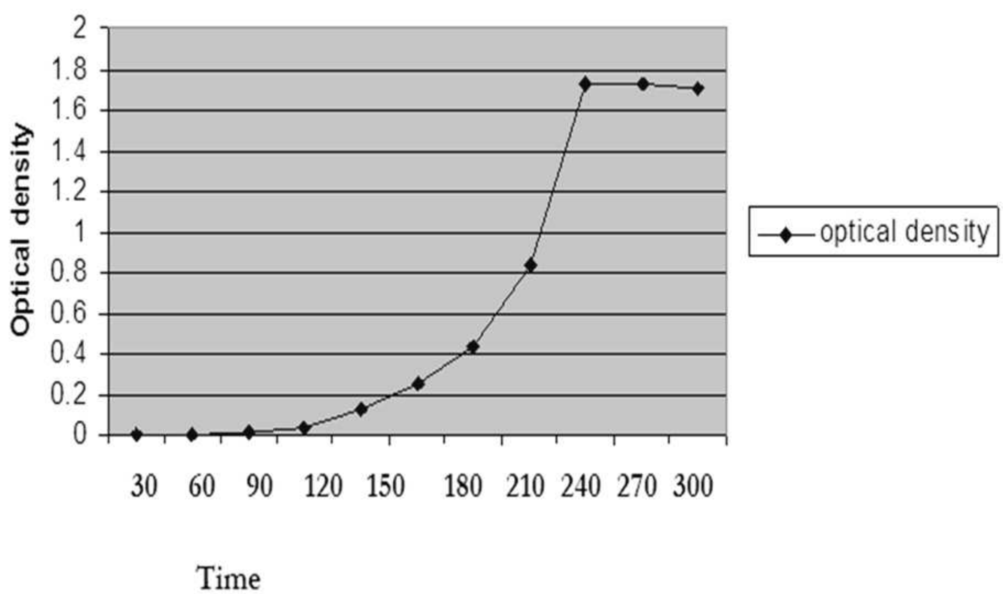

Fig. 1. The growth curve of the isolated bacterium in the batch culture

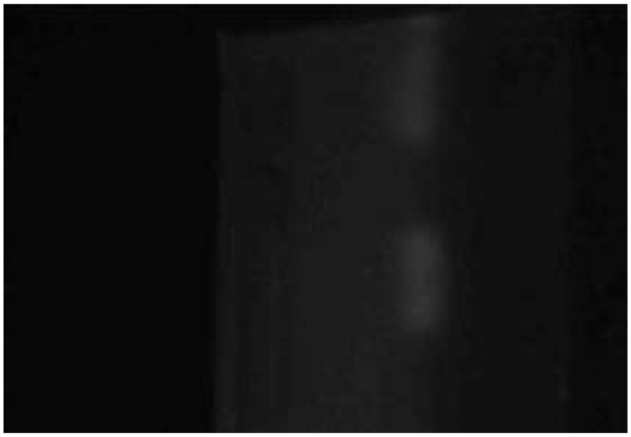

Fig. 2. Appearance of single band of plasmid on agarose gel electrophoresis

Table 1. Appearance of bacterial colonies in the culture medium. Data represent the mean of three replicates.

Days after culture	Designed culture medium with free of nitrogen	Designed culture medium with free of nitrogen with glucose	Designed culture medium with free of carbon
1	00	00	00
2	10 ± 2	18 ±1	14 ± 2
3	25 ± 2	29 ± 3	26 ± 2
4	35 ± 1	42 ± 2	39 ± 1
5	35 ± 1	80 ± 1	53 ±1

plasmid was detected through horizontal electrophoresis. A prominent single band was observed upon staining with ethidium bromide (Fig. 2). This indicated that the bacterium had a single or the different plasmids of same molecular weight. In the studies of carbofuran degradation, where the bacteria were grown in presence of pesticide and it was recorded that with in 7 days, in mixed culture, there the convertion of carbofuran to its metabolic inactivated product was observed (Table 2). The initiation of degradation of the compound was observed at (24 hrs of culture) stationary phase,

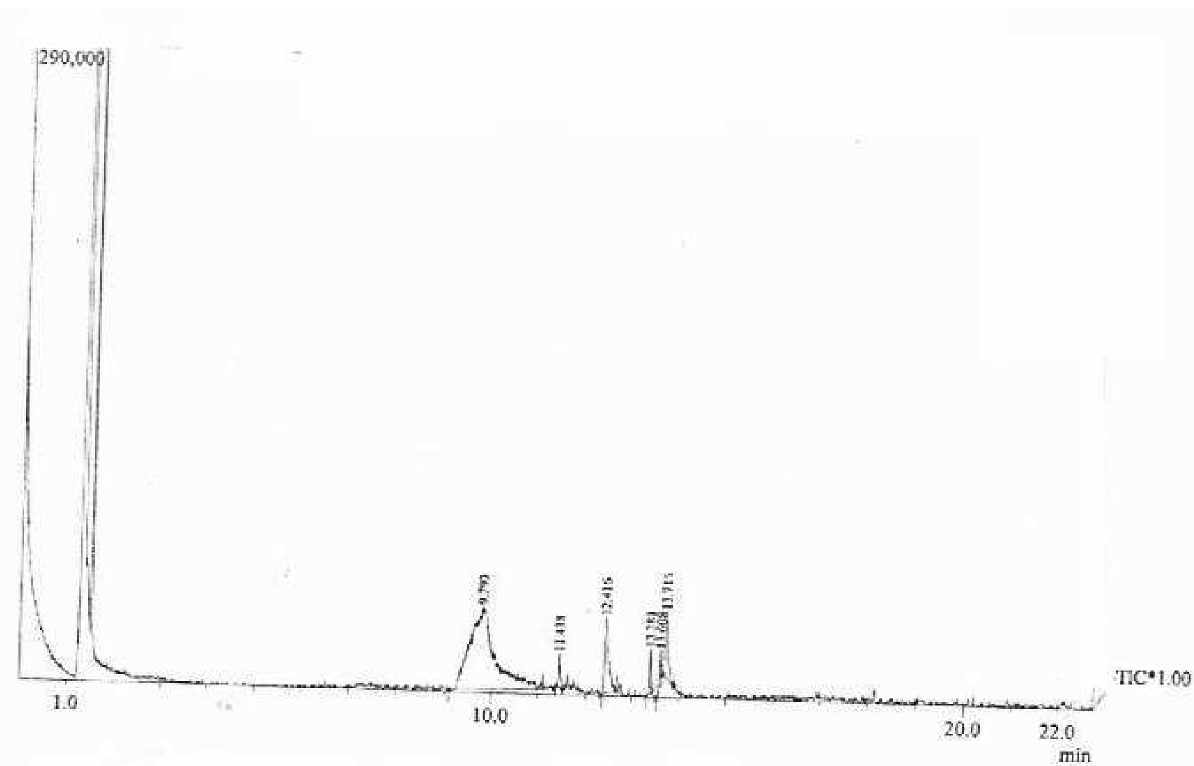

Fig. 3. Chromatogram of GC-MS analysis of biodegradation compounds

Table 2. The percentage of degradation of carbofuran to carbofuran phenyl in the mixed culture with the bacterium. Data represent average of 3 replicates ± SEM

Days after culture	Degradation (%)
1	02
3	23
5	51
7	64
9	64

followed by enhanced degradation up to 7 days of inoculation and then remained constant. However, it was observed, in total, the maximum degradation of cabofuran with the isolated bacterium was recorded as 64 per cent at *in vitro* cultures. Further, the degradation of the compound was confirmed by thin layer chromatography (TLC) and Gas chromatography and Mass Spectroscopy (GCMS) as shown in Figure. 3. Both the results indicated that carbofuran has been converted to crabofuran phenyl which is a less toxic substance.

CONCLUSION

The present work can be concluded that the isolated bacterial strain is a potential biodegrader of carbofuran compound. The further study of the bacterium will help us in establishing phylogenetic relationship among different strains of bacteria involved in the process of degradation and may further help us in development / transformation of other bacteria to acquire biodegradation process through recombinant DNA technology and to serves as new data base of microorganism with degradation capacity. Moreover, especially on the molecular characterization of the plasmid may help in developing certain strains of bacteria for bioremediation of carbamate group of pesticides *per se.*

REFERENCES

Aneja, K.R 2002. Pure culture of microbes and determination of bacterial growth by turbidity measurement In : *Experiments in Microbiology Plant Pathology and Biotechnology*. pp 223

Beirne, B. P. 1975. Biological control attempts by introductions against pest insects in the field in Canada. *Canad. Ent.* , **107** : 225-36.

Cock, M. J. W. 1985. Review of Biological Control of Pests in the Commonwealth Caribbean and Bermuda. *C.Á.B. International*. pp 218

Flaherty, D. L. and L. T. Wilson. 1999. Biological control of insects and mites on grapes. In: *Handbook of Biological Control: Principles and Applications*. Academic Press, San Diego, New York. Pp 1046

Howard, L. O. 1996. The parasite element of natural control of injurious insects and its control by man. *J. Econ. Ent.* **19**: 271-82.

Luck, R. F. 1981. Parasitic insects introduced as biological control agents for arthropod pests. In: *Handbook of Pest Management in Agric*ulture pp 125-84.

Price, P. W. 1974. *Evolutionary Strategies of Parasitic Insects and Mites*. Plenum Press, New York and London. Pp 224

Singleton, P. 1999. Bacteria in Biology, In*: Biotechnology and Medicine* (5th ed.). Wiley Press. pp 444–54

Van der Hoek, W, Konradsen, F, Athukorala, K, and Wanigadewa, T. 1998. Pesticide poisoning: a major health problem in Sri Lanka. *Soc Sci Med.*; **46**: 495–504

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Mechanisation of cotton harvesting in India: Status, issues and challenges

S. K. SHUKLA, V. G. ARUDE, P. G. PATIL, G. MAJUMDAR AND S. VENKATKRISHNAN

Ginning Training Centre, Central Institute for Research on Cotton Technology, Nagpur -

E-mail : skshukla2000@gmail.com

ABSTRACT : In India, efforts into mechanisation of cotton crops are being attempted for more than a decade. Numerous designs have been evaluated by Govt. and Private organisations. However, most of the designs failed to perform under field conditions. A commercial cotton picker prototype suitable for Indian cotton farms is being evaluated for harvesting of cotton crops sown on high density planting system for two cotton seasons. This prototype is developed by attaching the picker head of the worldwide used 6-rows cotton picker at the side of a 55 hp tractor with some specially designed attachments. The issues like cost of processing, yarn realisation percentage, fibre losses during cleaning operations, development of suitable genotypes, agronomic practices etc. that need to be addressed for successful mechanical harvesting of cotton crops in India are discussed in great length. The fibre parameters and trash analysis data pertaining to the field trials are also presented in this study. The field evaluation data and fibre quality indices reveal that the commercial picker to be launched for mechanical picking of cotton in India is promising.

Key words : Cotton harvesting mechanisation, cotton processing cost, defoliation, harvesting efficiency, losses, neps, Spindle picker, trash content

Cotton is a very important cash crop of India and it plays a leading role in the industrial and agricultural economy of the country. Cotton is main source of income in India for around 6 million farmers and about 40-50 million people are directly or indirectly engaged in cotton trade and processing [1]. India tops the world in cotton acreage and is the second only to China in cotton production with 35.1 million bales (*i.e.*170 kg each) production in 2012-13 [2]. Unlike the developed cotton growing countries (*i.e.* USA, Australia, Israel, etc.) where cotton is harvested using sophisticated machines called as cotton pickers/strippers, entire cotton in India is picked manually [3]. Moreover, there are around 28 cotton growing countries that harvest part of its cotton crop using cotton pickers/strippers. Cotton picking machines have spindles that pick (twist) the seed cotton from the opened cotton bolls (Fig. 1). The twisted seed cotton is doffed with the help of moist doffing pads wherefrom it is directed into a bucket attached at the top of the picker. Whereas cotton stripping machines use rollers equipped with alternating bats and brushes to knock the open bolls from plants to a conveyor (Fig. 1). The cotton picker plucks only the open bolls while the stripper strips both the open and the unopened bolls and some plant matters as well. Hence the stripped cotton contains more than two-three times trash content as compared to the machine picked cotton.

Though, the researches into cotton mechanisation in India started in around year 2000 under the NATP programme, the requirement of a suitable cotton mechanisation system has been felt very badly in last couple of years as the cost of cotton picking in India (i.e.

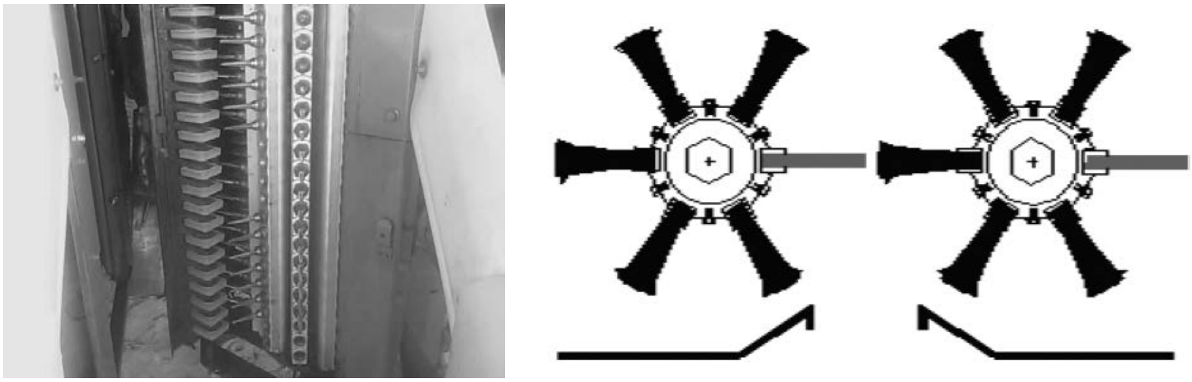

Fig. 1. Images of picker head (right) and stripper rolls with bats (left)

around Rs. 4-6/kg seed cotton) has doubled in recent past mainly due to high inflation rate, migration of landless farm labours to cities and implementation of the *National Rural Employment Guarantee Act* (*NREGA*). Moreover, the shortage of labours during peak season results in the delay in sowing of the next crop leading to low yield [4]. At present, the manual cotton picking cost in India is around 10-12 per cent of the total cotton selling price, which is much higher than the harvesting cost of any other crop grown in India. For instance, the rice harvesting cost is almost negligible compared to its selling price *i.e.* 0.01 per cent. In order to meet the scarcity of labour and to reduce the cotton picking cost, efforts need to be concentrated on mechanization of cotton harvesting [3].

In the last ten years, cotton acreage has been growing at an average annual rate of around 3%. However, the average cotton yield in India is steady at around 500 kg/ha compared to world average of 730 kg/ha (ICAC, 2010). The low yields of cotton in India are primarily due to rainfed cultivation, inadequate inputs usage, untimely field operations and inefficient crop production technologies. The lack of disease resistant and high yielding cotton varieties/ hybrids also contribute in low yield of cotton. Low cotton yield and increased cotton cultivation cost have reduced the farm income leading to a series of suicides committed by farmers in some cotton growing states of India. The mechanisation of cotton harvesting particularly in USA, Brazil, Turkey, etc. has led to significant increase in cotton productivity, decrease in cultivation cost and increase in farm income. Heinicke and Grove [5] have demonstrated positive effects on cotton yield by using machines for cotton harvesting in USA. Similarly, Isin*et al.,* [6] have also reported considerable increase in cotton yield in Turkey on adoption of mechanical picking. A recent study by Konduru *et al.,* [7] has estimated potential increase in cotton farm income in India *i.e.* around Rs. 10,000/ac, if cotton is harvested mechanically. The increased productivity in case of mechanical picking is mainly achieved by reducing row-row and plant-plant spacing which in turn increases the plant density by 4-5 times than the conventional method. The reduction in plant spacing is obtained by controlling the height and branches of the cotton plants.

Though, the farmers are in dire need for a suitable cotton harvester and it has potential for increasing productivity, farm income, availability of labours for other crops etc., there are many issues and challenges that need to be addressed for adoption of cotton harvesters in

India. Adoption of mechanical harvesting in India is not dependent upon just the availability of suitable harvesters. The successful adoption of cotton harvester in other part of world suggests the requirement of holistic change in the entire chain of cotton cultivation including breeding and agronomic practices, harvesting and processing operations for successful adoption of cotton pickers as all operations are interlinked. This paper explores the status, issues and challenges that require group efforts from scientists and technologists belonging to cotton breeding, agronomy, farm machinery, extension, cotton processing etc. for successful adoption of cotton harvesting and its economic feasibility.

Appropriate plant physiology : Manual crop harvesting, particularly manual cotton picking is mostly independent upon plant height, width, location of bolls on plants, etc. However, there are certain limitations in the functionality and capability of even highly sophisticated harvesting machines. It is required to suitably modify the plant physiology through genetic or breeding interventions to obtain a particular plant height, branch structure, locations of fruits on plants, etc. in order to successfully automate the harvesting operations. Mechanical cotton pickers require medium plant height *i.e.* around 1.0-1.2 m with minimum branches and bushes i.e. spreading into 0.5-0.6 m diameter for efficient and viable harvesting of cotton crops. Countries that employ mechanical cotton pickers have developed suitable plant genotypes having required plant physiology amenable for mechanical picking. Cotton varieties with the right plant architecture and height, amenable for mechanical harvesting need to be developed for mechanical pickers to work efficiently and effectively.

It is normal practice to sow about 25,000 to 40,000 plants/ac (two to three plants/foot of a row in conventional spaced rows: 38-40 inches) for picker type varieties [8] whereas 2 to 3 feet spacing/plant (*i.e.* 5000-6000 plants per acre) is the normal practice for sowing of *Bt* seeds in India. Though, the reduction of plant height and width results in less bolls/plant, the increased plant population per acre area results in more number of bolls than the convention method leading to increased productivity. Cotton breeders and scientists from government research organisations and private seed companies are working for past couple of years to develop cotton varieties, which are suitable for mechanical picking. M/S. Ankur Seeds Pvt. Ltd. and M/S. Nuzivedu Seeds Ltd. are working in tandem with M/S. John Deere India, a cotton picker manufacturer for development of suitable plant genotypes. In this cotton season, M/S. Ankur Seeds Pvt. Ltd. have evaluated its regular products, Ankur 8120 and Ankur 3028 hybrid *Bt* seeds for their suitability for mechanical pickers. It shows that instead of developing exclusive genotypes amenable for mechanical picking, most of the work is directed on identifying varieties from their regular products. The growth of the plants was regulated by using growth inhibitors or growth regulators developed by M/S. Bayer Crop Sciences, a German well known company for production of chemicals required for mechanical harvesting of cotton.

Synchronise boll opening : It is normal practice in India to harvest the cotton crops in 3-4 pickings because of occurrence of multiple flowering and fruiting of cotton that lead to development of 3-4 flushes of cotton bolls [9]. Though cotton pickers collect only fully open bolls and leave the unopened bolls on the plants unaffected, it's not economically viable to operate the mechanical picker more than once primarily because of high diesel prices prevailing in the market. Delayed cotton pickings have also been attempted in earlier trials in order to allow unopened bolls to get matured. However, it did not work well as locules of bolls which were opened initially got unattached from its burrs and had fallen on the ground. Moreover, there is every chance for damage of opened bolls unpicked for a long time due to incessant rain and wind. There are some chemicals that are used to enhance the rate of boll openings. However, these chemicals affect the natural boll-opening process, but they do not cause bolls or fibre to mature faster. There is chance of affecting the maturity and micronaire values of fibres by improper timing and doses of chemicals. Hence, there are requirement for identification of proper chemicals, optimisation of its doses, timing etc.

Development of suitable cotton pickers : The average farm holding in India is less than 2 hectare and the size of Indian cotton fields is very small [10]. The machine pickers available in the world market are very large in size and capacity [11], hence they are unsuitable for cotton pickings in small Indian cotton farms. Dedicated work at different Indian Cotton Research Institutes and by Indian as well as foreign agricultural machinery manufacturers is going on for past one decade towards development of a suitable cotton picking machine for small sized Indian farms. Researchers have tried different picking methods (*i.e.* pneumatic suction, pneumatic suction cum picking brushes, sensor techniques, hand held picking machine, etc.) for harvesting of cotton [12]. However, most of these methods did not perform well under field conditions [13].

It has been observed by the numerous researchers that among the different methods tested for cotton picking, the conventional spindle type picker based mechanism appeared to be working satisfactorily for picking of cotton. This method was also evaluated in Indian cotton farms by cotton pickers imported from then USSR [14]. However, the further progress in this direction was constrained by the fall of former USSR.

Fig. 2. Single row cotton picker attempted in India

The potential for mechanical pickers in Indian market have attracted the global giants like John Deer and New Holland for development of mechanical pickers suitable for picking of cotton from small cotton fields. Efforts have been made by the researchers and agricultural machinery manufacturers for attaching the cotton picking heads in the side of existing tractors so as to avoid the high initial investment in purchasing a self-propelled spindle type picker. John Deer India has already come out with a single row cotton picker in which picker head is attached at the side of a 55 hp tractor (Fig. 2). This machine is being evaluated for two cotton seasons at different part of the country along with several stakeholders including ICAR research institutes, state govt. officials, seed producing companies, chemical manufacturers, ginneries etc. [15]. New Holland is also carrying out the field testing of a cotton picker prototype specially designed for the Indian market expecting to be launched in 2-3 years' time. The proposed picker is tractor propelled and tailored specifically for the small farms suitable for Indian farmers.

Defoliation : Defoliation is the shedding of cotton leaves that naturally occurs when leaves become physiologically mature (Fig.3). It is required to artificially shed the cotton leaves using certain chemicals called as defoliants or harvest aids in order to eliminate the main source of stain and trash to enter the cotton while harvesting. Defoliation also helps in improving lint grades, reduces moisture, improves storage of cotton and opens the green and unopened bolls [16]. There are a number of chemicals used for defoliation of cotton meant for mechanical harvesting [17]. The effectiveness of defoliation depends on several factors like temperature and rain fall at the time of treatment, periods of cloudy weather after treatment, soil moisture and nitrogen levels, calibration of application rates, etc. Weather conditions at the time of application and three to five days following application have a significant effect on cotton response to harvest aids. Harvest aids are most active when temperature, sunlight intensity and relative humidity are high. The yield and condition of the cotton crop are also deciding factor for the choice of defoliants. Optimisation and standardisation of defoliants still remain a challenge in India causing 4-5 per cent additional trash content in harvested cotton using mechanical picker in form of un-shedded leaves. It has also been observed in several cases where defoliation did not work properly due to certain unfavourable conditions resulting in 20-25 per cent trash content in harvested cotton against 10-12 per cent for properly defoliated cotton.

Fig. 3. Cotton crop before defoliant application (left) and after defoliation (right)

Field losses in terms of left over and fallen bolls : The cotton picker machine plucks the cotton from open bolls while unopened bolls are left over on the plants (Fig. 4). Moreover, some part of the open bolls is also left un plucked on the plants and some part of harvested cotton falls on the field while harvesting. Field evaluation jointly conducted by CIRCOT, Nagpur, CICR, Nagpur and CIAE, Bhopal of a two row cotton picker (model no. 9935) imported from John Deere, USA during cotton seasons 2005-2006 revealed field losses to the tune of 10-15 per cent [18]. The issue of harvesting losses was also raised by group of farmers who witnessed the demonstration of cotton picker harvesting at Abohar, Punjab. The field loss due to mechanical harvesting of any crop is not a new phenomenon. Though combine harvesters also result in field losses, combine harvesting of wheat has become indispensible particularly in Northern part of India. The net margin of cotton farmers has bottomed out in recent past due to increased inputs and labour costs. However, benefits of cotton picker in terms of increased productivity by means of high plant density system and reduction of labour cost for picking have potential to offset the harvesting losses.

Fig. 4. Hand picking of cotton (left) and mechanical harvesting of cotton crop (right)

Requirement of additional pre-cleaning machinery : It is widely reported in literature [12, 14, 19-21] that the machine picked cotton contains around 10-15 per cent trash content, which includes burs, sticks, leaves, grasses, motes, etc. However, the imperfection of defoliants under Indian conditions has led to increase in trash content in mechanical picked cotton by 4-5 per cent. Moreover, trash content in range of 20-25 per cent was also observed in certain cases where defoliation did not work properly. The handpicked cotton particularly available in India hardly contains trash content in range of 2-5 per cent depending upon cotton varieties, skill of pickers, precautions taken during picking, number of flushes etc. There is requirement of a cylinder type pre cleaner developed by CIRCOT for pre cleaning of handpicked cotton prior to ginning. The cylinder type pre-cleaner removes around 25-30 per cent trash content from the cotton and the remaining trashes are removed in pneumatic conveying and lint cleaning operations. Finally, the bales processed from properly managed modern Indian ginneries contain around d”1 per cent trash content using a cylinder type pre cleaner and lint cleaner. On contrary, there is requirement of 3-4 number of additional special type pre cleaning machines based on combing and extracting principles for making the machine picked cotton ginnable. Cylinder cleaners use rotating spiked cylinders that open and clean the seed cotton by scrubbing it across a grid bars that allows the trash to sift through (Fig. 5). The cylinder type pre-cleaners are meant for removal of kawadi/immature bolls, fine/pin trash, separation of metallic pieces and opening of the cotton. However, machine picked cotton contains large vegetative content like sticks and burrs and significant amount of green and dry leaves that require combing and extracting actions for dislodging of large and fine trashes. Large foreign matters are removed by combing action and centrifugal force in extractor type cleaners as seed cotton is pulled across a series of grid bars by a rotating saw/toothed cylinders. This cleaning mechanism is referred as the "sling-off" principle.

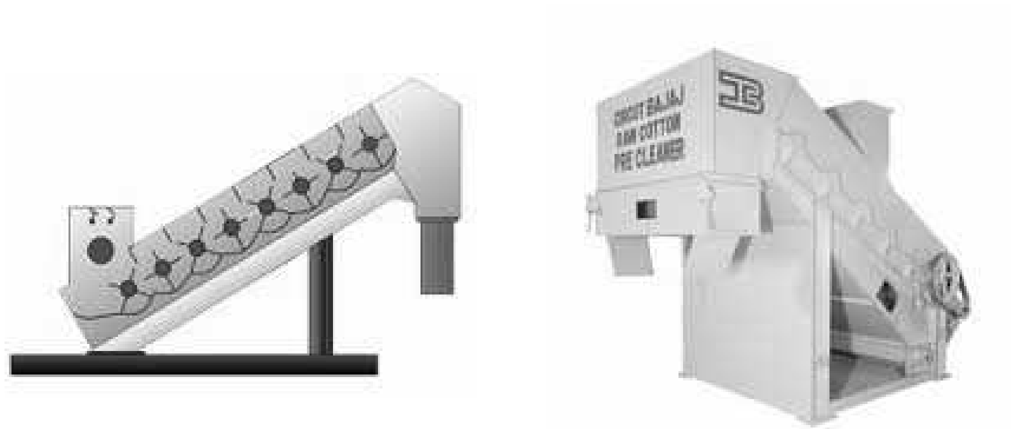

Fig. 5. Internal view of cylinder pre cleaner (left) and cylinder pre cleaner designed by CIRCOT and developed and marketed by BSI, Nagpur (right)

Cleaning machines based on sling off principles are not readily available in local market and import is unviable and very costly. Ginning Training Centre (GTC) of CIRCOT, Nagpur is working in tandem with the cotton picker research group towards development of a cleaning system suitable for pre-cleaning of the machine picked cotton. Research group at GTC of CIRCOT has reported bringing down trash content to around 4-6 per cent level from initial trash content of 12-14 per cent for machine picked cotton using set of cleaning machinery developed at GTC of CIRCOT under the NATP project. GTC of CIRCOT is also collaborating with M/s. Bajaj Steel Industries, Nagpur for optimisation and standardisation of cleaning machinery for processing of the machine picked cotton. However, formation of higher neps, reduction in staple length of fibres and spinning of fibres during pre cleaning etc. are some issues that need to be addressed before launching to the ginners.

Moreover, the machine picked cotton is likely to be wetter than handpicked cotton due to application of water for doffing of cotton in case of mechanical picking. The efficiency of pre-cleaning machines depends to considerable extent on moisture in cotton. There is requirement of optimum moisture content in cotton for pre cleaning machine to function effectively. The greater the moisture, lower the efficiency and *vice versa*. Hence, there is requirement of a tower drier system for bringing down moisture content in machine picked cotton to optimum level prior to pre cleaning.

Trash content and fibre parameters for the machine picked cotton : The assembly of machines displayed above have been evaluated jointly by CIRCOT, Nagpur and M/s. BSI, Nagpur for its performance for cleaning of the machine picked cotton at Abohar, Punjab during ginning season 2013-2014 (Fig. 6). Table 1 and Table 2 depicts that the trash content in the machine picked cotton was 13.3 and 22.2 per cent for properly and improperly defoliated cottons, respectively. Hence it can be concluded that the defoliation plays a major role in deciding the trash content in the machine harvested cotton.

Fibre quality parameters analysed using HVI does not show any significant effect on fibre qualities for cotton variety Ankur 8120 after cleaning it in set of machines. However, significant differences in fibre parameters were observed for cotton variety Ankur 3028 after cleaning it in the set of machines. It is probably

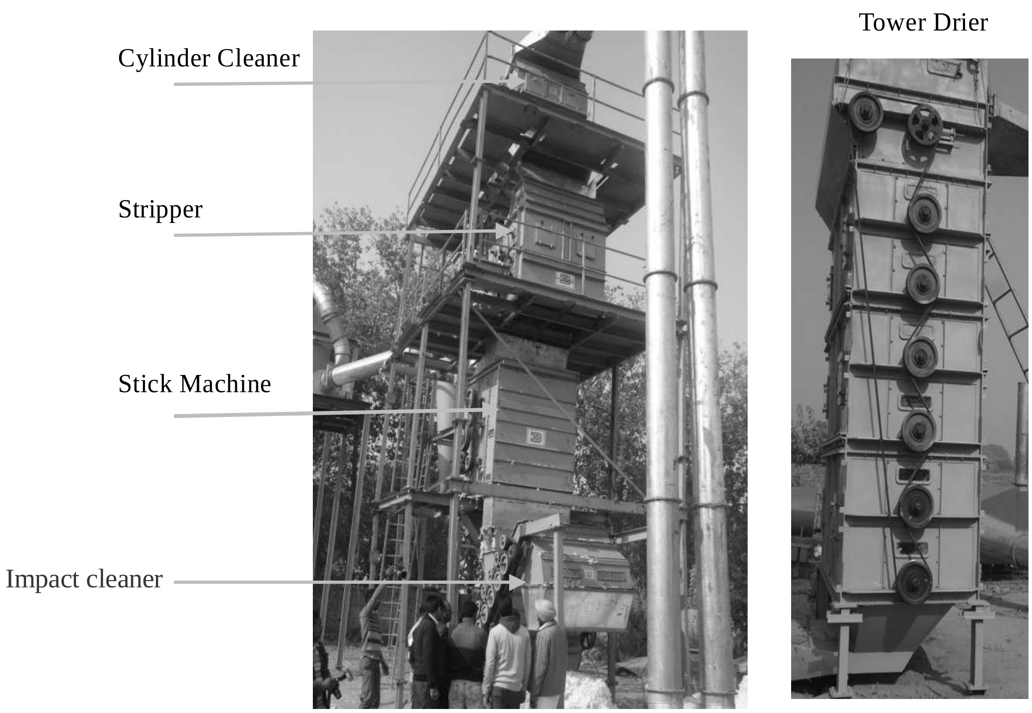

Fig. 6. Set of additional cleaning machines required for processing of the machine picked cotton (Courtesy: M/s. Bajaj Steel Industries, Nagpur)

Table 1. Trash content in properly defoliated cotton (Ankur 8120)

Seed cotton (g)	Lint (g)	Cotton seed (g)	Trash content	Bracts/ Burrs	Sticks	Green leaves	Immature seeds/ motes	Dry leaves	Total Trash content
300	104	196	(g)%	2.742.60	0.480.50	0.580.60	0.120.10	9.99.6	13.813.3

Table 2. Trash content in poorly defoliated cotton (Ankur 3028)

Seed cotton (g)	Lint (g)	Cotton seed (g)	Trash content	Bracts/ burrs	Sticks	Green leaves	Immature seeds/ motes	Dry leaves	Total trash content
300	104	196	(g)(%)	4.564.40	0.80.8	0.960.90	0.20.2	16.5815.90	23.122.2

Table 3. HVI results for machine picked cotton (MPC) and machine picked pre-cleaned cotton (MPPC)

Seed cotton	Average result upto 10 reading						
	UHML (mm)	ML (mm)	MIC (µg/inch)	Strength (g/tex)	UI (%)	SFI (%)	EL (%)
MPC A 8120	29.4	23.9	4.4	30.2	81.0	8.7	4.6
MPPC A 8120	29.4	23.6	4.3	29.6	80.1	8.7	4.7
MPC A 3028	28.1	22.8	4.9	29.1	81.2	8.9	4.5
MPPC A 3028	27.7	22.0	4.2	28.2	79.5	11.3	5.1

due to reason that the Ankur 3028 contained much higher amount of trash content than to Ankur 8120 that led to deterioration in the fibre qualities. Fibre parameters analysed using AFIS shows significant differences in the fibre parameters for both the cotton varieties tested in this study after pre cleaning (Table 4). Fibre neps that used to be around d”100 count/g for roller ginned Indian cotton have increased to around 250 count/g. Moreover, upper quartile length (UQL) measurements that corresponds to upper half mean length (UHML) of HVI values shows significant loss in fibre length (about 0.5 mm) for the pre-cleaned cottons. Higher neps count leads to reduction in yarn realisation and increase in fibre losses in spinning mills resulting in reduction in mill profits. The AFIS data clearly shows that the pre cleaning machines need to be optimised and fine-tuned in order to avoid damage in fibre qualities. Table 5 shows that the trash content in the machine picked cotton has been brought down to 4.2 per cent and 5.7 per cent, respectively for the properly defoliated and improperly defoliated cottons.

Increased investment for fixed and processing cost : As mentioned in the preceding section that the machine picked cotton requires 3-4 numbers of additional cleaners for its processing. The cost of additional pre cleaners including a tower drier and conveying system is around Rs. one crore at prevailing market rates for a ginning plant of around 10-15 bales/ha capacity. It is very difficult to convince the Indian ginners to invest additional one crore rupees in procurement of pre cleaning machinery meant for handling of the machine picked cotton.

Increased cost of processing : The additional cleaning machinery requires around 100 HP additional connected electrical load and

Table 4. AFIS results for machine picked cotton (MPC) and machine picked pre-cleaned cotton (MPPC)

Seed cotton	Length module test result					Nep module test result				
	L(w) mm	UQL (w) (mm)	SFC (w) (mm)	L (n) mm	SFC (n) % (mm)	5(%) L(n) (mm)	Fiber Neps Count /g	**Mean size (ìm)**	Seed coat Neps Count /g	**Mean size (ìm)**
MPC A# 8120	23.9	31.0	14.0	17.6	37.1	35.5	168	**661**	16	**1451**
MPPC A 8120	23.1	30.4	16.4	16.5	41.2	35.2	280	**666**	14	**1364**
MPC A 3028	20.9	27.1	18.6	15.5	42.1	31.6	206	**630**	10	**1214**
MPPC A 3028	19.7	25.7	21.4	14.5	45.5	29.6	242	**679**	15	**1172**

#Ankur

Table 5. Reduction of trash content in pre cleaning operations

Seed cotton	Initial trash content in the machine picked cotton (%)	Trash content in the pre cleaned cotton (%)	Reduction in the trash content (%)
Ankur 8120	13.3	4.2	68.4
Ankur 3028	22.2	5.7	74.3

a heating device for drying of the machine picked cotton in the tower drier. There is requirement of around 60 litre diesel and 60 unit electrical energy in an hour for running of the tower drier and the cleaning machinery resulting in expenditure of around Rs. 5000/h (including maintenance and operator cost) for pre cleaning and drying of the machine picked cotton. The increased cost on the processing comes to around Rs. 1/kg of seed cotton, which is around 67 per cent of the total cost of ginning of the handpicked cotton (around Rs. 1.5/kg seed cotton).

Increased losses of fibres in ginneries : It is well known fact that the ginners particularly in India are reluctant for employing even a light cylinder pre cleaner and post cleaner. It is mainly because of the reasons that the pre cleaners lead to losses of some fibres *i.e.* 1 per cent along with the removed trash content. However, most of the separated fibres are short fibres. The study by Arude *et al.,* [22] has showed processing losses to the tune of 1.8 and 3.3 per cent, respectively for handpicked cotton of the first and the second pickings. The application of 3-4 pre cleaners for the processing of the machine picked cotton shall lead to increased loss in fibres that may concern to the ginners.

CONCLUSIONS

This study presents an overview of status, issues and challenges for mechanisation of cotton harvesting in India. The following conclusions can be drawn from this work:

- Spindle type picker specially developed for harvesting of Indian cotton is found to be promising.
- It is required to develop suitable varieties/hybrids to obtain suitable plant types that are required for successful operation of the mechanical picker.
- There is requirement for adoption of certain agronomic practices like application of growth regulators, boll openers, defoliants etc. for successful operation of the mechanical picker.
- Trash content in the machine picked cotton was 13.3 per cent and 22.2 per cent for properly and improperly defoliated cottons, respectively.
- There is requirement of 3-4 additional cleaners based on sling off principles and a tower drier for processing of the machine picked cotton.
- Ginners shall have to make a substantial investment in machinery to get their gins properly equipped to process the machine picked cotton.
- The processing cost of the machine picked cotton is 67 per cent higher compared to the handpicked cotton.
- There is slight deterioration in the fibre parameters due to processing in additional cleaners.
- Spinners shall have to make some investment in machinery to process bales with higher neps content.

REFERENCES

ICAC. 2010. India: Country statement on cotton. In: *69th Plenary Meeting of the International Cotton Advisory Committee at Lubbock*. Texas, USA: ICAC.

CCI. 2014. Statistics. [status May 31, 2014]. "Available through:" http://cotcorp.gov.in/statistics.aspx].

Shukla, S.K., Patil, P.G., Arude, V.G. 2006. Design development and performance evaluation of saw cylinder cleaner for mechanically picked cotton. *Agricultural Mechanization in Asia, Africa and Latin America (AMA),* **37 :** 30-34.

Prasad, J., Majumdar, G. 1999. The present practices and future needs for mechanization of cotton picking in India. *Agricultural Engineering Today,* **23 :** 1-20.

Heinicke, C., Grove, W.A. 2008. Machinery has completely taken over: the diffusion of the mechanical cotton picker, 1949–1964. *Journal of Interdisciplinary History,* **xxxix :** 65-96.

Isin, F., Isin, S., Uzmay, A. 2009. Economic analysis of cotton production and adoption of harvest mechanization: A case study of the Aegean Region of Turkey. *Food, Agriculture and Environment (JFAE),* **7 :** 387-93.

Konduru, S., Yamazaki, F., Paggi, M. 2013. A study of mechanization of cotton harvesting in India: Implications for international markets. Cotton Incorporated, USA. p. 1-8.

Hake, K., Burch, T., Harvey, L., Kerby, T., Supak, J. 1991. Plant population, In: *Physiological Today: National Cotton Council.* p. 1-4.

Bhagwat, R. 2014. Cotton survived excess rains, thrived on late rains, In: *Times of India, April 29, 2014*. Times of India, April 29, 2014: Nagpur.

Anonymous. 2012. Agriculture in India. *Wikipedia (status Sept 21, 2012),*"Available through:" http://en.wikipedia.org/wiki/Agriculture_in_India.

Corley, T.E., Stokes, C.M. 1964. Mechanical cotton harvester performance as influenced by plant spacing and varietal characteristics. *Transactions of the ASAE,* **7 :** 281-86; 296.

Muthamilselvan, M., Rangasamy, K., Ananthakrishnan, D., Manian, R. 2007. Mechanical picking of cotton - a review. *Agric. Rev.,* **28 :** 118-26.

Asola, C.N. 1996. Field performance evaluation of a manually opearted cotton picker. *Agricultural Mechanization in Asia, Africa and Latin America (AMA),* **27 :** 24-26.

Singh, T.H., Brar, A.S., Thind, R.J.S., Prakash, R., Vithal, B.M. 1992. Mechanical picking of cotton in Punjab: a preliminary study. *J. Indian Soc. Cott. Improv.*: 62-67.

Anonymous. 2014. COTTON VISION 2020: Note on private sector initiatives in realizing the vision. FICCI. p. 1-10.

Leon, R.G., Wright, D.L., Brecke, B.J. 2013. 2013 Cotton defoliation and harvest aid guide. IFAS Extension, University of Florida, United States of America.

Barber, L.T., Hayes, R.M., Dodds, D.M., Reynolds, D.B. 2013. Mid-South cotton defoliation guide. University of Arkansas, Cooperative Extension Service Printing Services, United States Department of Agriculture. p. 3-10.

Prasad, J. 2005. Final report on adoption and refinement of cotton picker and cleaning system. Central Institute of Agricultural Engineering, Bhopal, India. p. 61.

Sui, R., Thomasson, J.A., Byler, R.K., Boykin, J.C., Barnes, E.M. 2010. Effect of machine fibre interaction on cotton fibre qulity and foreign matter particle attachment to fibre. *The Journal of Cotton Science,* **14 :** 145-53.

Sandhar, N.S. 1999. Present practices and future needs of mechanization of cotton picking/ harvesting in India, In: *Indo-Uzbek Workshop on Agricultural Research*: CIAE, Bhopal, MP, India.

Anthony, W.S., Mayfield, W.D. 1994. Cotton ginners handbook: The United States Department of Agriculture (USDA).

Arude, V.G., Shukla, S.K., Manojkumar, T.S., Makawana, D.N. 2010. Evaluation of cotton processing loss in modernized Indian roller ginneries. *Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA),* **41 :** 24-27.

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Secondary pests' outbreak in *Bt* cotton

RISHI KUMAR, ALKA CHOUDHARY AND SHIVANGI

Central Institute for Cotton Research, Regional Station, Sirsa- 125 055

E-mail : rishipareek70@yahoo.co.in

There are an estimated 67000 pest species that damage agricultural crops, of which approximately 9000 species are insects and mites (Ross and Lembi, 1985). Insect-pests are the major cause of crop losses (Kumar *et al.,* 2008). Averages of 15 per cent of crops worldwide are currently lost to insects (Maxmen, 2013). More than 1326 species of insects have been reported in commercial cotton fields worldwide (Hargreaves, 1948). India is currently the biggest producer of *Bt* cotton in the world since 2012 (Krishna and Qaim, 2012) having largest area under cotton cultivation. Certain pest species of cotton have few deleterious effects on production. These species are called 'minor' or 'secondary' species. The status and the relative economic importance of these different pests vary depending on the agro-ecosystem considered and changes in response to selection pressure to which they are subject.

Commercialized *Bt* cotton through expression of toxic crystalline (Cry) proteins from the soil bacteria *Bacillus thuringiensis* (*Bt*), have effectively managed their target pests (Carriere *et al.,* 2010; Tabashnik *et al.,* 2008). Besides its efficacy against target pest and worldwide adoption, the technology remains under controversy and surrounded by uncertainty (Andow *et al.,* 2009; Lovei *et al.* 2009; Shelton *et al.,* 2009) with respect to potential long term impact especially the development of insect resistance and the impact on secondary insect pests (Lovei *et al.,* 2009; Smale *et al.,* 2006, Garcia and Altieri, 2005).

The Bt cotton has very specific site to act so any detrimental impact on non target organisms (NTO) is expected to be lower than that imposed by broad-spectrum insecticides (Areal and Riesgo, 2015; Guoping Li *et al.,* 2010; Marvier *et al.,*2007; Cattaneo *et al.,* 2006; Naranjo., 2005) applied to manage the primary/ target pests. The reduced use of insecticides may further allow for a higher diversity and density of beneficial arthropods (Lu *et al.,* 2012; Naranjo, 2005). In the absence of target pests, a further concern is that other insect species that are not susceptible to the expressed toxin will develop into secondary pests and cause significant damage to the crop (Wu and Guo.,2005; Sharma and Ortiz., 2000). The development of secondary pests certainly affects other levels of trophic chain which could be of high economic and ecological relevance. The development and effects of secondary pests on *Bt* crops, although of high importance, has received limited attention (Harper, 1991, p.22) and ignoring secondary pests can lead to devastating crop damage that may continue over a considerable period of time. In the event of a secondary pest outbreak, additional pest management interventions are required. The secondary pest's outbreaks and its main causes in *Bt* cotton in India and worldwide has been discussed in the chapter.

Secondary pests in *Bt* cotton crop : Emergence of secondary pests in cotton is a matter of concern as in agricultural ecosystem two relevant phenomena *i.e.* pest resurgence and outbreaks of secondary pests are considered as ecological backlash events. Where pest resurgence refers to a situation in which a suppressed target pest population unexpectedly rebounds following a pest control action, exceeding the economic injury level (Hardin *et al.,* 1995). But the outbreak of secondary pest is the emergence of a pest other than that originally targeted by an agricultural intervention (the 'targeted' or 'primary' pest), and can be seen as 'replacement' for the primary pest (Hardin *et al.,* 1995; Metcalf, 1980).

A secondary pest is a 'non-targeted pest that has historically posed small or negligible economic threat, but which could be affected directly by a dose expressed in a *Bt* crop, or indirectly through changes in insecticide-use patterns (FIFRA Scientific Advisory Panel ,1998) . Outbreaks of secondary pests is 'an explosive increase in the abundance of a particular species that occurs over a relatively short period of time (Berryman, 1987, p.3) but Metcalf (1986) termed it as 'type II resurgence' which can arise when the primary pest is strongly affected by a pest management strategy, yet is replaced by another pest not affected by this strategy. The causes responsible for both pest resurgence and outbreaks of secondary pests are relatively similar which includes reduction in the number of natural enemies and removal of competitors (Hardin *et al.,* 1995; Ripper, 1956). In broader context, concept of secondary pests is linked with all living organisms that are not affected by newly expressed compounds in *Bt* crops, and can be potentially exposed, directly or indirectly, to the target crop and/or its products in the agro-ecosystem where *Bt* crops will be released or in adjacent habitats' (Arpaia, 2010, p.14). A lethal or sub lethal effect of a *Bt* crop might occur in non target organisms through direct exposure to the *Bt* toxin or indirectly due to changes in the ecosystem on which that species depends (Snow, *et al.,* 2005). To assess the impact of *Bt* crops impact on non target organisms at different trophic levels, an acquaintance with the majority of arthropod species prevalent in a given agro-ecosystem must be known.

Outbreak of secondary insect pests in *Bt* cotton : The outbreak of secondary pests in cotton is suspected because once the primary pest is brought under control, secondary pests have a chance to emerge due to the lower pesticide applications in *Bt* cotton cultivars. According to the studies conducted recently on emergence of secondary pest, more pesticide sprayings are needed over time to control emerging secondary pests, such as aphids, spider mites, and lygus bugs. Worldwide there are studies where *Bt* cultivars has proved their efficacy against target pests but their impact on the environment is still uncertain (Qaim and Zilberman, 2003).

It is premature to comment that adoption and cultivation of *Bt cotton* crop will not affect non target pests/secondary insect species due to the limited number of non target species studied (Lovei *et al.,*2009) available. However, previous studies on the side-effects of *Bt* toxins on non-target organisms yielded conflicting results; some researchers documented that the *Bt*-cotton has little or no effect on the non- target insects (Yunhe *et al.,*2011;Sujii *et al*, 2008; Liu *et al.,* 2006; Naranjo, 2005, Head *et al.,*2005) while others demonstrated that the population densities of non target insects such as cotton aphid, whitefly, and green leaf bug increased in cotton fields (Nguyen, *et al.,*2008; Fitt *et al.,* 1994) and no change in population densities of sucking insects or of the foliage feeder *Myllocerus undecimpustulatus* on Bollgard, Bollgard II and conventional cultivars (Dhillon and Sharma, 2013, Mann *et al.,* 2010). Considerable information has been generated on the relative efficacy of *Bt* and conventional cotton in many countries (Tabashnik, *et al.,* 2008; Qaim and Zilberman, 2003) but reports regarding the performance of *Bt*-cotton in the tropics are few due to the recent adoption of *Bt* technology and also the tropics are often more complex and consist of several crops that serve as alternate and collateral hosts for bollworms and other sucking pests. This has lead to differences in performance of the different *Bt*-cultivars (Gopalaswamy *et al.,* 2009; Sharma and Pampapathy, 2006) in these countries.

The pest scenario in Indian cotton ecosystem is changing and adoption of *Bt* cotton has not only changed the cultivation profile, but also the pest scenario. While there is a decline in the pest status of bollworms; the sap feeders, viz. aphids, jassids, mirids and mealy bugs are emerging as serious pests (Akoijam *et al.,* 2014; Dhaliwal *et al.,* 2010; Vennila., 2008). Recently, mirid bugs, Ragmus spp. and *Creontiades biseratense* (Distant) appeared in epidemic form in Dharwar (Karnataka) and Coimbatore (Tamil Nadu). Mirid bug had appeared in severe form throughout the Karnataka, with most aggressive status in Haveri district (Manohar *et al.,* 2012; Rohini *et al.,* 2009; Udikeri *et al.,* 2009). Also, some of the minor pests like thrips, *Thrips tabaci* Linderman; shoot weevil, *Alcidodes affaber* Aurivillius and stem weevil, *Pempherulus affinis* (Faust) are becoming serious on *Bt* cotton (Sarode *et al.,* 2009). Various species of mealy bugs have started appearing in serious proportions on field crops, vegetables, fruits and ornamentals (Tanwar *et al.,* 2007). In fact, mealy bugs have become indicator insects for the current ecosystem alterations due to slow changes in climate during the period from 2002 to 2005. Among these, *Phenacoccus solenopsis* Tinsley on cotton and *Paracoccus marginatus* Williams and Granara de Willink on papaya have become quite serious (Rajendran, 2009; Tanwar *et al.,* 2007). During 2006, *P. solenopsis* appeared for the first time on cotton crop in Punjab and caused severe losses in some pockets of Ferozepur, Muktsar and Bathinda districts (Dhawan and Saini, 2009). Since then this pest has spread to several states like Haryana, Rajasthan, Maharashtra and Gujarat and southern states (Atwal and Dhaliwal, 2009; Nagrare *et al.,* 2009; Monga *et al.,* 2009). As Bollgard (Cry1Ac) cotton does not provide protection against tobacco caterpillar, *Spodoptera litura* (Fabricius), it continues to inflict heavy losses in several cotton growing regions of India (Dhaliwal *et al.,* 2010). New reports of damage by tea mosquito, *Helopeltis bradyi* (Waterhouse) and gall midge, *Dasineura gossypii* damage in Karnataka on MRC 6918 and RCH 708 *Bt* cottons are of concern (Kumar and Gopalaswami, 2014). A severe outbreak of whitefly has been observed in the north cotton growing zone of India during 2015.

Factors associated with secondary insect pests' outbreak in *Bt* cotton crop : The employment of *Bt* crops might have non nutritive negative effects on agricultural ecosystem interactions and on farm profits (Sharma and Ortiz, 2000; Wolfenbarger and Phifer, 2000).Secondary pests, which before were of minor importance, might now find favorable conditions and themselves become major pests (Lu *et al.,* 2010). Three main factors responsible for an outbreak of secondary pest species with the use of *Bt* cotton are (i) reduction in application of broad-spectrum insecticide for target pests; (ii) impact on natural enemy populations; or (iii) reduction in interspecific competition due to the absence of primary/target pest. Additionally under Indian conditions the cultivation of large number of *Bt* cotton genotypes (hybrids) may also be having an important role in secondary pest outbreak.

Genotypic reaction : By May 2012, there were 1128 *Bt* cotton hybrids available in the Indian market (IGMORIS, 2012). *Bt* cotton currently occupies over 93 per cent of the area under cotton cultivation. Genetic makeup of the plant is very much important to confer tolerance to biotic and abiotic stress under natural conditions. Sucking pests have emerged as major pests causing significant economic losses for which one of the possible reasons is that the donor parent Coker 312 itself is highly susceptible to sucking pests (Kumar and Gopala Swamy,2014).Furthermore these hybrids escaped the rigorous screening procedure against insect-pests prior to approval. 54 *Bt* cotton hybrids were evaluated for genetic tolerance to sucking pests and leaf reddening under rain fed farming, where differential reactions in hybrids to sucking pest recorded, providing an option for cotton stake holders to choose tolerant hybrids so that indiscriminate insecticide sprays can be reduced (Nagrare *et al.,*2014). The hybrids released for cultivation has different plant type, morph-physiological traits, agronomic requirement and the microclimate of the crop is disturbed if these conditions are not followed.

Reduction in broad spectrum insecticide applications in *Bt* cotton and secondary pests outbreak : Due to its efficacy against target pests , introduction of *Bt* technology brought significant decreases in insecticide application among adopters, at least during the early years and considerably alleviated the negative impacts associated with the use of such insecticides (Krishna and Qaim, 2012; Kouser and Qaim, 2011; Birader and venilla, 2008). Despite warnings from several authors (Sharma and Ortiz, 2000; Wu and Guo, 2005) that some secondary insect pests could appear in such numbers that they become key pests in *Bt* crop fields, specific measures to overcome their population increases were not taken. Consequently, there have been outbreaks of secondary pests which were previously controlled by the insecticide applications originally targeting the primary pest (Prasad *et al.,* 2014; Kranthi, 2012; Pemsl *et al.,* 2011; Lu *et al.,* 2010). This situation has been particularly evident in *Bt* cotton production in China. Less than 3 years after its introduction in 1998, several pest groups including whiteflies, plant hoppers, aphids, mirids and mealy bugs increased in number (Yang *et al.,*2005a; Men *et al.,* 2004). After the introduction of *Bt* cotton, cotton cultivators in India have been facing new problems with insect pest management in many parts of the country, mostly presumed to be a consequence of low insecticide usage. New sucking pests have emerged as major pests causing significant economic losses. Insecticide usage for bollworm control decreased after 2004 from 6454 to 222 metric tonnes and usage for sucking pest control increased after 2006 from 2735 to 6372 metric tonnes in 2011 (Kranthi, 2012). It is known that the usage of synthetic pyrethroid for bollworm control had significant negative impact on the incidental populations of *Spodoptera* sp. and several other miscellaneous bugs including the mirid bugs, *Creontiodes biseratence* (Distant) and Ragmus sp. The reduction of pyrethroid and several conventional insecticides on *Bt* cotton is presumed to have led to an enhanced infestation of several non target species such as mirid bugs, mealy bugs, thrips and tobacco cutworm (Kumar and Gopala Swami, 2014)

Association between reduction in natural enemies and secondary pests' outbreak in *Bt* cotton crop : Natural enemies are critical to ecosystem functioning by inhibiting the excessive multiplication of potential pests in agricultural systems through 'biological control' (Bianchi *et al.,* 2006; Wilby and Thomas, 2002). Natural enemies alone may be sufficient in some cases to keep secondary pest populations under economic injury thresholds (Wolfenbarger *et al.,* 2008; Hardin *et al.,* 1995).The employment of *Bt* crops and the consequent reduction in insecticide usage increase the significance of the function of natural enemies to control secondary pests (Naranjo, 2005).Hence, a major concern related to the growing of *Bt* crops is their potential impact on the abundance of natural enemies (Marvier *et al.,* 2007; Poppy and Sutherland, 2004). Predators were less abundant in *Bt* cotton fields compared to unsprayed non *Bt* control fields. Fewer specialist parasitoids of the target pest occurred in *Bt cotton* crop fields compared to unsprayed non *Bt* controls, but no significant reduction was detected for other parasitoids. Numbers of predators and herbivores were higher in *Bt* crops compared to sprayed non *Bt* controls (Wolfenbarger *et al.,* 2008).

The selectivity of Cry toxins is not entirely known, with the potential for unintended effects on beneficial species which may influence other non susceptible pests (Lovei *et al.,* 2009). However, interactions between prey and natural enemies are extremely complex. Many laboratory and field research studies evaluated the impact of *Bt* toxins on the natural enemies of potential secondary pests. Several laboratory studies reported no significant effects on natural enemies (Andow *et al.,* 2009) while others have indicated negative effects (Dhillon and Sharma., 2009; Gonzalez-Zamora *et al.,* 2007). Results from studies performed at a field level show similar variation; some found no significant impacts while other reported negative effects. Natural enemies are often present in higher numbers in insecticide-free conventional fields than on *Bt* fields (Naranjo, 2009; Marvier *et al.,* 2007). It is also widely accepted that the use of insecticides has larger direct negative effects on natural enemies than does the use of *Bt* crops (Romeis *et al.,* 2009; Wolfenbarger *et al.,* 2008; Cattaneo *et al.,* 2006). Overall, this suggests that in field settings, where *Bt* cotton crops do have an impact on natural enemies, but these are not as strong as the direct effect of insecticide. The reports indicating both negative and positive effects of cry toxins on natural enemies need further detailed and long term laboratory and field studies.

The impact of *Bt* toxins on natural enemies can occur through direct and/or indirect effects (Romeis *et al.,* 2006).
Direct impacts might occur due to the ingestion of the insecticidal protein. The mechanism of action of several available *Bt* toxins is still unknown or in conclusive (Lovei *et al.,* 2009; Lovei and Arpaia, 2005) leading to the assumption that *Bt* toxins may cause similar negative effects on predators as they do on the target herbivores (Andow *et al.,* 2006).

Manifestations of Indirect effects might be through reductions in prey/host populations or in the nutritional quality of the prey. Impacts of the toxin on herbivores may manifest at a sub lethal level which can affect life parameters such as life span and fecundity (Romeis *et al.,* 2004). There is evidence that the low nutritional quality of prey items after they have ingested *Bt* proteins has a significant impact on the performance, development and even survival of natural enemies. Moreover, high mortality rates in the target species may cause a reduction in specialist natural enemies, which themselves can be important prey for generalist predators. Additionally, prey species in general might migrate to non-*Bt* fields in search of preferable food resources. Thus, if prey availability for secondary pest predators in *Bt* fields is scarce, predators might be encouraged to 'migrate' to adjacent conventional crops, negatively affecting their abundance within *Bt* fields (Sisterson *et al.,* 2007). Hence, it may be possible that these negative impacts will permit the development of secondary pests in the crop itself or even in neighboring crops (Gross and Rosenheim, 2011; Gutierrez *et al.,* 2006). A clear and strong understanding about the direct and indirect effects of *Bt* cultivars on natural enemies is important as these insects play a major role in biological control of primary as well as secondary pests.

Secondary insect pests' outbreak due to species replacement : Competition may play an important role in the dynamics of herbivorous insects (Kaplan and Denno, 2007) and cotton crop has so far been reported to be attacked by 1326 insect species (Hargreaves 1948) where the phenomenon of species replacement become highly relevant. However, the importance of replacement between primary and secondary pests has generally been ignored in conventional agriculture (Denno *et al.,* 1995; Hardin *et al.,* 1995) and especially in *Bt* cropping. *Bt* cotton crop, similar to insecticides, is an artificially imposed disturbance on the ecosystem; hence, it is not surprising that niche rearrangement occurs. It is possible that when a primary pest is successfully controlled by a *Bt* toxin, a non-susceptible species starts to utilize the newly available ecological resource (Gross and Rosenheim, 2011; Hardin *et al.,* 1995). This situation occurs in cases where, prior to the pest management treatment, the primary pest is a dominant competitor species and the secondary pest is a weak competitor (Shivankar *et al.,* 2007).

In *Bt* cotton in the USA, stink bug pests, specifically *Nezara viridula* L. and *Euschistus servus* S., have recently become a severe problem in the absence of the target pests *Heliothis zea* and *H. virescens* (Zeilinger *et al.,* 2011). As *Bt* cropping expands worldwide; it is of critical importance to determine the key species–susceptible and non susceptible pests–which might compete for resources within the same *Bt* crop. An increase in abundance of tobacco caterpillar, *Spodoptera litura* in bollgard cotton in North India during 2005-06 was due to suppression of primary bollworm, *Helicoverpa armigera* .

Secondary pests' outbreak and its impact on *Bt* cotton crop : In the early years of *Bt* cropping, there were reports of increased profitability in overall production due to 40%–60% reductions in insecticide applications alongside increased crop yields, as compared to non- adopters (Rui *et al.,* 2005; Bennett *et al.,* 2004; Qaim and Zilberman, 2003; Huang *et al.,* 2002; Pray *et al.,* 2002; Fitt, 2000). Nonetheless, there were early concerns about the potential for secondary pest outbreaks due to the decrease in insecticide applications (Morse *et al.,* 2005; Qaim, 2003; Wu *et al.,* 2002).

Cotton From the worldwide 24.3 million hectares cropped with *Bt* cotton, India, China and USA account for 11.0, 4.2 and 4.1 million hectares, respectively (James, 2013), with very high adoption rate (James, 2013). Until the end of the 20th century, insecticides were intensively applied to control the cotton bollworm (Wu and Guo, 2005). However, in the early 1990s, the effective control of this pest became problematic, as cotton bollworms became resistant to most insecticides due to their repetitive and overuse (Deguine *et al.,* 2008; Wu and Guo, 2005; Kranthi *et al.,* 2002,).

In China after the introduction of *Bt* technology in 1999, insecticide applications in *Bt* cotton fields dropped from about 61 kg/ha (20 applications) per year, to approximately 12 kg/ ha (6.6 applications) per year (Huang et al ,2002). By 2002, this figure started to increase, reaching on average 15.6 kg/ha (10.7 applications) per year of insecticides, of which 4.7 kg were used against cotton bollworm, and the remaining against lygus bug and other pests (Pemsl et al, 2011). By 2005, farmers applied roughly the same amount against the cotton bollworm, but the amount sprayed against secondary pests had increased by 20 per cent, to a total of 18.6 kg/ha (14.2 applications) per year (Pemsl et al 2011). The drop in insecticide use and the ineffectiveness of *Bt* cotton against these secondary pests has led to a reversal of the ecological role of cotton (Li *et al.,* 2011; Lu *et al.,* 2010).Conventional cotton had been a population sink for the miridbug secondary pest, while now a day's *Bt* cotton fields are a source of these pests (Lu *et al.,* 2010,) and in India the sap feeders, *viz.,* aphids, jassids, mirids and mealy bugs are emerging as serious pests (Akoijam *et al.,* 2014; Dhaliwal *et al.,* 2010; Vennila, 2008). This has led to a situation where there are no major differences in the total quantity and expenditure in insecticide application between *Bt* and conventional cotton farmers (Zhao *et al.,* 2011). In India, usage of insecticides for sucking pest control increased after 2006 from 2735 to 6372 metric tons in 2011 (Kranthi, 2012).

But according to Huang *et al* 2014, cotton production is still effective and farmers are applying fewer sprayings in early season, with fewer cases of human poisoning. Moreover, a higher survival of generalist arthropod predators has been recorded (ladybirds, lacewings and spiders), providing additional biocontrol to neighboring crops, such as maize and soybean (Huang *et al.,* 2014; Lu *et al.,* 2012).

Indian cotton farming is comparable with China, with numerous small-scale farmers (Qaim *et al.,* 2009; Huang *et al.,* 2002;).Recent evidence showed that secondary pests are now posing a major problem (Nagrare *et al.,* 2009), with farmers battling against non target insects (Ramaswami *et al.,* 2012; Stone, 2011) found no significant difference between adopters and non-adopters in terms of insecticide use. Elsewhere in the world, similar issues to the Chinese and Indian cases have been reported in cotton. Adopting farmers are either still using significant numbers of insecticide applications to control secondary pests, or the damage caused by these pests has increased. Some examples include South Africa (Schnurr, 2012; Hofs *et al.,* 2006), Pakistan (Jaleel *et al.,* 2014), Australia (Wilson *et al.,* 2013), Brazil (Sujii *et al.,* 2013) and Mexico (Traxler and Godoy-Avila, 2004). The development of resistance in target pests and appearance of secondary pests has led to increase in number of applications to control these pests in cotton and quantity of insecticides used against these pests is also increasing pointing towards a more robust insecticide resistance management program for overall sustainability of cotton ecosystem.

CONCLUSION

The secondary pests are a matter of serious concern and need to be addressed with greater emphasis. The cotton crop worldwide has been reported to be attacked by large number of insect-pests species and there are chances of competitive displacement or acquisition of vacant niche by non competent species either in the absence of primary insect–pest species or due to reduction in insecticidal application or changes in natural enemies' scenario.

REFERENCES

Akoijam, R.,Telam,R.,Marangmai,L. 2014. Insect pest problems and its changing trends on crop losses. *Environment and ecology.*

Andow, D.A., L•ovei, G.L. and Arpaia, S. 2009. Cry toxins and proteinase inhibitors in *Bt* plants do have non-zero effects on natural enemies in the laboratory: rebuttal to Shelton *et al.,* 2009. *Environ. Entomol.* **38** : 1528–32.

Areal, F.J. and Riesgo, L. 2015. Probability functions to build composite indicators: a methodology to measure environmental impacts of genetically modified crops. *Ecol. Indic.* **52** : 498–516.

Arpaia, S. 2010. Genetically modified plants and "non-target" organisms: analysing the functioning of the agro-ecosystem. Collect. *Biosafety Rev.* **5** : 12–80.

Atwal, A.S. and Dhaliwal, G.S. 2009. *Agricultural Pests of South Asia and Their Management.* Kalyani Publishers, New Delhi.

Biradar V. K. and Vennila.S. 2008. Pest management for *Bt* cotton: Need for conservation biological control. *Curr. Sci.,* **95 :** 10

Bennett, R., Ismael, Y., Morse, S. and Shankar, B. 2004. Reductions in insecticide use from adoption of *Bt* cotton in South Africa: impacts on economic performance and toxic load to the environment. *J. Agric. Sci.* **142 :** 665–74.

Berryman, A.A. 1987. The theory and classification of outbreaks. In Insect Outbreaks (Barbosa, P. and Schultz, J., eds): 3–30. San Diego, CA: Academic Press.

Bianchi, F.J.J.A., Booij, C.J.H. and Tscharntke, T. 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proc. R. Soc. Lond. B Biol. Sci.* **273 :** 1715–27.

Carriere, Y., Crowder, D.W. and Tabashnik, B.E. 2010. Evolutionary ecology of insect adaptation to *Bt* crops. *Evol. Appl.* **3:**561–73.

Cattaneo, M.G., Yafuso, C., Schmidt, C., Huang, C., Rahman, M., Olson, C., Ellers-Kirk, C., Orr, B.J., Marsh, S.E. and Antilla, L. 2006. Farm scale evaluation of the impacts of *Bt* cotton on biodiversity, pesticide use, and yield. *Proc. Natl Acad. Sci.* USA, **103 :** 7571–76.

Deguine, J.-P., Ferron, P. and Russell, D. 2008. Sustainable pest management for cotton production. A review.*Agron. Sustain. Dev.* **28 :** 113–37.

Denno, R.F., McClure, M.S. and Ott, J.R. 1995. Interspecific interactions in phytophagous insects: competition reexamined and resurrected. *Annu. Rev. Entomol.* **40 :** 297–331.

Dhillon, M.K. and Sharma,H.C. 2009. Effects of *Bacillus thuringiensis* ä-endotoxins Cry1Ab and Cry1Ac on the coccinellid beetle, *Cheilomenessex maculatus* (Coleoptera, Coccinellidae) under direct and indirect exposure conditions. *Biocontrol Science and Technology* DOI: 10.1080/ 09583150902783801 : 407-20.

Dhillon M, Sharma H 2013. Comparative studies on the effects of *Bt-Bt* and non *Bt* cotton on arthropod diversity, seed cotton yield and bollworms control. *Jour. Environ. Bio.* **34 :** 67–73.

Dhaliwal, G.S. and Koul, O. 2010. *Quest for Pest Management: From Green Revolution to Gene Revolution*. Kalyani Publishers, New Delhi.

Dhawan, A.K. and Saini, S. 2009. First record of *Phenacoccusso lenopsis* Tinsley (Homoptera: Pseudococcidae) on cotton in Punjab. *J. Insect Sci.* **22 :** 309-10.

FIFRA Scientific Advisory Panel. 1998. Transmittal of the final report of the *FIFRA scientific advisory panel* subpanel on *Bacillus thuringiensis* (*Bt*) plant-pesticides and resistance management. 9–10 February. Docket No. OPPTS-00231 59.

Fitt, G.P.,Mares, C.L., Llewellyn, D.J. 1994. Field evaluation and potential ecological impact of *Bt* cottons (*Gossypium hirsutum*) in Australia.*Biocontrol.Sci. Technol.* **4 :** 535-48.

Fitt, G.P. 2000. An Australian approach to IPM in cotton: integrating new technologies to minimize insecticide dependence. *Crop Prot.* **19,** 793–800.

Garcýa, M., Ortego, F., Castanera, P. and Farinos, G.P. 2012. Assessment of prey-mediated effects of the coleopteran-specific toxin Cry3Bb1 on the generalist predator Atheta coriaria (Coleoptera: Staphylinidae). *Bull. Entomol.Res.* **102,** 293–302.

Garcia, M.A. and Altieri, M.A. 2005. *Bt* crops: implications for biodiversity and sustainable agriculture. *Bull. Sci. Technol. Soc.* **25,** 335–53.

Gopalaswamy S.V.S., Prasad N.V.V.S.D., and Rao N.H.P. 2009. *Bt* crops: A major component of Integrated Pest Management-An Overview. *Ind. Jour. Crop Sci.*, **4 :** 1-10.

Guoping Li, Hongqiang Feng, Peiyu Chen, Shaoying Wu, Bing Liu, and Feng Qiu.2010. Effects of *Bt* Cotton on the Population Density, Oviposition Behavior, Development, and Reproduction of a Non target Pest, *Adelphocoris suturalis* (Hemiptera: Miridae) *Environmental Entomology* 39(4):1378-1387. doi: http://dx.doi.org/10.1603/EN09223

Gross, K. and Rosenheim, J.A. 2011. Quantifying secondary pest outbreaks in cotton and their monetary cost with causal inference statistics. *Ecol. Appl.* **21,** 2770–80.

Gutierrez, A.P., Adamczyk, J.J., Ponsard, S. and Ellis, C. 2006. Physiologically based demographics of *Bt* cotton pest interactions: II. Temporal refuges, natural enemy interactions. *Ecol. Model.* **191,** 360–82.

Hardin, M.R., Benrey, B., Coll, M., Lamp, W.O., Roderick, G.K. and Barbosa, P. 1995. Arthropod pest resurgence: an overview of potential mechanisms. *Crop Prot.* **14,** 3–18.

Hargreaves, H. 1948. List of Recorded Insects of the World. Commonwealth Institute of Entomology, London, 50 p

Harper, C.R. 1991. Predator prey systems in pest management. Northeast. *J. Agric. Resour. Econ.* **20,** 15–23.

Head, G., Moar, W., Eubanks, M., Freeman, B., Ruberson, J., Hagerty, A., Turnipseed, S. 2005. A multi year, large scale comparison of arthropod populations on commercially managed *Bt* and non *Bt* cotton fields. *Environ. Entomol.* **5 :**1257-66.

Hofs, J.-L., Fok, M. and Vaissayre, M. 2006. Impact of *Bt* cotton adoption on pesticide use by smallholders: a 2-year survey in Makhatini Flats (South Africa). *Crop Prot.* **25,** 984–88.

Huang, J., Rozelle, S., Pray, C. and Wang, Q. 2002. *Plant biotechnology* in China. *Science*, **295,** 674–76.

Huang, J., Mi, J., Chen, R., Su, H., Wu, K., Qiao, F. and Hu, R. 2014. Effect of farm management practices in the *Bt* toxin production by *Bt* cotton: evidence from farm fields in China. *Transgenic Res.* **23,** 397–406.

James, C. 2013. Global Status of Commercialised Biotech/GM Crops: 2013, ISAAA Brief No. 46. Ithaca, NY: *International Service for the Acquisition of Agri-Biotech* Applications. ISBN 978-1-892456-55-9.

Jaleel, W., Saeed, S., Naqqash, M.N. and Zaka, S.M. 2014. Survey of *Bt* cotton in Punjab Pakistan related to the knowledge, perception and practices of farmers regarding insect pests. Int. *J. Agric. Crop Sci.* **7,** 10.

Kumar, G.V.S and. Gopala Swamy S. V. S. 2014. A duo-decennium of *Bt* cotton adoption in India – An overview. *Curr. Biotica* **8 :** 322-40.

Kaplan, I. and Denno, R.F. 2007. Interspecific interactions in phytophagous insects revisited: a quantitative assessment of competition theory. *Ecol. Lett.* **10,** 977–94.

Kouser, S. and Qaim, M. 2011. Impact of *Bt* cotton on pesticide poisoning in smallholder agriculture: a panel data analysis. *Ecol. Econ.* **70,** 2105–13.

Kranthi, K. R., Russell, D., Wanjari, R., Kherde, M., Munje, S., Lavhe, N. and Armes, N. 2002. In-season changes in resistance to insecticides in *Helicoverpa armigera* (Lepidoptera:Noctuidae) in India. *Jour. Eco. Ento.*, **95 :** 134-42.

Kranthi, K. R. 2012. *Bt* cotton Question and Answers. *Indian Society for Cotton Improvement* (ISCI), Mumbai, 70pp.

Krishna, V.V. and Qaim, M. 2012. *Bt* cotton and sustainability of pesticide reductions in India. *Agric. Syst.* **107,** 47–55.

Kumar, S.; Chandra, A. and Pandey, K. C. 2008. "*Bacillus thuringiensis* (*Bt*) *Bt* crop: An environment friendly insect-pest management strategy", *Journal of Environmental Biology*, **29** : 641-53.

Li, G., Feng, H., McNeil, J.N., Liu, B., Chen, P. and Qiu, F. 2011. Impacts of transgenic *Bt* cotton on a non target pest, *Apolygus lucorum* (Meyer-D•ur) (Hemiptera: Miridae), in northern China. *Crop Prot.* **30,** 1573–78.

Lu, Y., Wu, K., Jiang, Y., Xia, B., Li, P., Feng, H., Wyckhuys, K.A.G. and Guo, Y. 2010. Mirid bug outbreaks in multiple crops correlated with wide-scale adoption of *Bt* cotton in China. *Science,* **328,** 1151–54.

Lovei, G.L., Andow, D.A. and Arpaia, S. 2009. *Bt* insecticidal crops and natural enemies: a detailed review of laboratory studies. *Environ. Entomol.* **38,** 293–306.

Liu, J., Chen,J., Peng,Y., Liu,F. 2006. Dynamic analysis of distribution patterns of the spiders in a cotton field by pitfall traps. Chinese Bull. *Entomol.*3, 300e304.

L•ovei, G. and Arpaia, S. 2005. The impact of transgenic plants on natural enemies: a critical review of laboratory studies. *Entomol. Exp. Appl.* **114,** 1–14.

Lu, Y., Wu, K., Jiang, Y., Guo, Y. and Desneux, N. 2012. Widespread adoption of *Bt* cotton and insecticide decrease promotes biocontrol services. *Nature,* **487,** 362–65.

Lu, Y., Wu, K., Jiang, Y., Xia, B., Li, P., Feng, H., Wyckhuys, K.A.G. and Guo, Y. 2010. Mirid bug outbreaks in multiple crops correlated with wide scale adoption of *Bt* cotton in China. *Science,* **328 :** 1151–54.

Mann, R.S., Gill, R.S. Dhawan, A.K. Shera, P.S. 2010. Relative abundance and damage by target and non target insects on Bollgard and BollgardII cotton cultivars .*Crop Protection* **29 :** 793–801.

Manohar, V. S., Udikeri, S. S., Patil, S. B., Bath,R., Yadahali, K. B. 2012. Seasonal dynamics of mirid bug (*Creontiades biseratense* Distant.) population in *Bt* cotton in Haveri district of Karnataka, *Karnataka J. Agric. Sci.,* **25** : 276-77.

Marvier, M., McCreedy, C., Regetz, J. and Kareiva, P. 2007. A meta-analysis of effects of *Bt* cotton and maize on non target invertebrates. *Science,* **316,** 1475–77.

Men, X., Ge, F., Edwards, C.A. and Yardim, E.N. 2004. The influence of pesticide applications on *Helicoverpa armigera* Heubner and sucking pests in *Bt* cotton and non *Bt* cotton in China. *Crop Prot.* **24,** 319–24.

Metcalf, R. 1980. Changing role of insecticides in *crop protection. Annu.Rev. Ento.* **25 :** 219–56.

Metcalf, R. 1986. The ecology of insecticides and the chemical control of insects. In: *Ecological Theory and Integrated Pest Management Practice* (Kogan, M., ed), 251–298. New York: Wiley.

Maxmen, A. 2013. "Crop pests: under attack", *Nature,* **501 :** 15-17.

Morse, S., Bennett, R. M. and Ismael, Y. 2005. Genetically modified insect resistance in cotton: some farm level economic impacts in India. *Crop Protection,* **25 :** 984-88.

Monga, D., Kumar, Rishi, V. Pal and Jat, M. C. 2009. Mealy bug a new pest of cotton crop in Haryana: a survey. *Jour. Insect Sci.* **22 :** 100-03.

Nagrare, V., Kranthi, S., Biradar, V., Zade, N., Sangode, V., Kakde, G., Shukla, R., Shivare, D., Khadi, B. M. and Kranthi, K. R. 2009. Widespread infestation of the exotic mealybug species, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), on cotton in India. *Bull. Entomol.* Res. **99 :** 537–41.

Nagrare V.S., Deshmukh A.J., Bisane A.K. 2014. Relative Performance of *Bt* Cotton Hybrids against Sucking Pests and Leaf Reddening under Rainfed Farming. *Entomol Ornithol Herpetol* 3:134. doi:10.4172/2161-0983.1000134.

Naranjo, S.E. 2005. Long-term assessment of the effects of *Bt* cotton on the abundance of non target arthropod natural enemies. *Environ. Entomol.* **34 :** 1193–1210.

Naranjo, S.E. 2009. Impacts of *Bt* crops on non-target invertebrates and insecticide use patterns. CAB Reviews: *PAVSNNR* **4 :** 1-23.

Nguyen, T. C., Sujii, E. R., Wilson, L. J., Underwood, E., Andow, D.A., MaiVan, H., Zhai, B., HoVan, C. 2008. Potential effect of *Bt* cotton on non target herbivores in Vietnam. In: Environmental Risk Assessment of Genetically Modified Organisms: Challenges and Opportunities with *Bt* Cotton in Vietnam, vol.4.CabI, Wallingford UK, pp.138-75.

Pemsl, D.E., Voelker, M., Wu, L. and Waibel, H. 2011. Long term impact of *Bt* cotton: findings from a case study in China using panel data. *Int. J. Agric. Sustain.* **9 :** 508–21.

Poppy, G.M. and Sutherland, J.P. 2004. Can biological control benefit from genetically-modified crops? Tritrophic interactions on insect resistant *Bt* plants. *Physiol. Entomol.* **29 :** 257–68.

Prasad, R.V, Reddy, R.U and Reddy, D.V. 2014. The impact of *Bt* technology on cotton cultivation on farm economy in Warangal district of Andhra Pradesh. *The Andhra Agricultural Journal*, **61 :** 484-86.

Pray, C., Huang, J., Hu, R. and Rozelle, S. 2002. Five years of *Bt* cotton in China–the benefits continue. *Plant J.* **31 :** 423–30.

Qaim, M. and Zilberman, D. 2003. Yield effects of genetically modified crops in developing countries. *Science*, **299 :** 900–02.

Qaim, M., Subramanian, A. and Sadashivappa, P. 2009. Commercialized GM crops and yield. Nat. Biotechnol. **27 :** 803–04.

Rajendran, T.P. 2009. Integrated pest management-Policy directions in the context of climate change. In: V.V. Ramamurthy, G.P. Gupta and S.N. Puri (eds) *Proc. Natn. Symp. IPM to Combat Emerging Pests in the Current Scenario of Climate Change*.January 28-30, 2009, Pasighat, Arunachal Pradesh, pp.8-13.

Romeis, J., Meissle, M., Raybould, A. and Hellmich, R. 2009. Impact of insectresistant transgenic crops on above-ground non-target arthropods. In Environmental Impact of Genetically Modified Crops (Ferry, N. and Gatehouse, A.M.R., eds), pp. 165–198. UK, Wallingford: CAB International.

Romeis, J., Meissle, M. and Bigler, F. 2006. Transgenic crops expressing *Bacillus thuringiensis* toxins and biological control. Nat. Biotechnol. **24 :** 63–71.

Romeis, J., Dutton, A. and Bigler, F.2004. *Bacillus thuringiensis* toxin (Cry1Ab) has no direct effect on larvae of the green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). *J. Insect Physiol.* **50 :** 175–83.

Ramaswami, B., Pray, C.E. and Lalitha, N. 2012. The spread of illegal *Bt* cotton varieties in India: biosafety regulation, monopoly, and enforcement. *World Dev.* **40 :** 177–88.

Ripper, W. 1956. Effect of pesticides on balance of arthropod populations. *Annu. Rev. Entomol.* **1 :** 403–38.

Rohini, R. S., Mallapur, C. P. and Udikeri, S. S. 2009. Incidence of mirid bug, *Creontiades biseratense* (Distant) on *Bt* cotton in Karnataka. *Karnataka J. Agric. Sci.,* **22 :** 680-81.

Ross MA, Lembi CA 1985. *Applied Weed Science.* Minneapolis, MN, USA: Burgess Publishing Co.

Rui, Y.K., Yi, G.X., Zhao, J., Wang, B.M., Li, J.H., Zhai, Z.X., He, Z. and Li. Q.X. 2005. Changes of *Bt* Toxin in the Rhizosphere of *Bt* Cotton and its Influence on Soil Functional Bacteria. *World Journal of Microbiology and Biotechnology,* **21 :** 1279-84.

Sarode, S.V., Kolhe, A.V. and Sable, V.R. 2009. IPM strategies for cotton in relation to climate change. In: V.V. Ramamurthy, G.P. Gupta and S.N. Puri (eds) *Proc. Natn. Symp.IPM Strategiesto Combat Emerging Pests in the Current Scenario of Climate Change.*

January 28-30, 2009, Pasighat, Arunachal Pradesh, pp.181-205.

Schnurr, M.A. 2012. Inventing Makhathini: creating a prototype for the dissemination of genetically modified crops into Africa. *Geoforum*, **43 :** 784–92.

Sisterson, M.S., Carriere, Y., Dennehy, T.J. and Tabashnik, B.E. 2007. Non target effects of *Bt* insecticidal crops: implications of source-sink population dynamics. *Environ. Entomol.* **36 :** 121–27.

Sharma, H. and Ortiz, R. 2000. *Bt*s, pest management, and the environment. *Curr. Sci.* **79 :** 421–37.

Sharma, H.C. and Pampapathy, G. 2006. Influence of *Bt* cotton on the relative abundance and damage by target and non target insect pests under different protection regimes in India. *Crop Protection*, **25 :** 800-13.

Shelton, A.M., Naranjo, S.E., Romeis, J., Hellmich, R.L., Wolt, J.D., Federici, B.A., Albajes, R., Bigler, F., Burgess, E.P. and Dively, G.P. 2009. Setting the record straight: a rebuttal to an erroneous analysis on *Bt* insecticidal crops and natural enemies. *Bt Res.* **18 :** 317–22.

Shivankar, V.J., Shyam, S. and Rao, C.N. 2007. Secondary pest resurgence. *In Encyclopedia of Pest Management*, Volume II (Pimentel, D., ed.), pp. 597– 601. Boca Raton: CRC Press.

Smale, M., Zambrano, P. and Cartel, M. 2006. Bales and balance: a review of the methods used to assess the economic impact of *Bt* cotton on farmers in developing economies. *Ag Bio Forum,* **9 :** 195–212.

Snow, A.A., Andow, D.A., Gepts, P., Hallerman, E.M., Power, A., Tiedje, J.M. and Wolfenbarger, L. 2005. Genetically engineered organisms and the environment: current status and recommendations. *Ecol. Appl.* **15 :** 377–404.

Stone, G.D. 2011. Field versus farm in Warangal: *Bt* cotton, higher yields, and larger questions. *World Dev.* **39 :** 387–98.

Sujii, E.R., Togni, P. H. B., Nakasu, E. Y. T., Pires, C. S. S., Paula, D. P. D., Fontes, E. M. G. 2008. Impact of *Bt* cotton on the population dynamics of the cotton aphid in green-house. *Pesqui.Agropecu.Bras.*10, 1251e1256.

Sujii, E.R., Togni, P.H.B., de A Ribeiro, P., de A Bernardes, T., Milane, P., Paula, D.P., Pires, C.S.S. and Fontes, E.M.G. 2013. Field evaluation of *Bt* cotton crop impact on nontarget pests: cotton aphid and boll weevil. Neotrop. *Entomol.* **42 :** 102–111.

Tabashnik, B.E., Gassmann, A.J., Crowder, D.W. and Carriere, Y. 2008. Insect resistance to *Bt* crops: evidence versus theory. *Nat. Bio technol.* **26 :** 199–202.

Tanwar, R. K., Jeyakumar, P. and Monga, D. 2007. *Mealybugs and Their Management.* National Centre for Integrated Pest Management, New Delhi.

Traxler, G. and Godoy-Avila, S. 2004. *Bt* cotton in Mexico. *AgBioForum*, **7 :** 57–62.

Udikeri, S. S., Patil, S. B., Shaila, H. M., Guruprasad, G. S., Patil, S. S., Kranthi, K. R. and Khadi, B. M. 2009. Mirid Menace – A potential emerging sucking pest problem in cotton. In*: Proc., 4th Asian Cotton Res. Devl. Network meeting* Anyang, China. *www. icac. org.*

Vennila, S. 2008. Pest management for cotton ecosystems or ecosystem management for cotton production? *Curr. Sci.* **94 :** 1351-52.

Wilby, A. and Thomas, M.B. 2002. Natural enemy diversity and pest control: patterns of pest emergence with agricultural intensification. *Ecol. Lett.* **5 :** 353–60.

Wilson, L., Downes, S., Khan, M., Whitehouse, M., Baker, G., Grundy, P. and Maas, S. 2013. IPM in the *Bt era:* a review of the challenges from emerging pests in Australian cotton systems. *Crop Pasture Sci.* **64 :** 737–749.

Wolfenbarger, L.L. and Phifer, P.R. 2000. The ecological risks and benefits of genetically engineered plants. *Science*, **290 :** 2088–93.

Wu, K., Li, W., Feng, H. and Guo, Y. 2002. Seasonal abundance of the mirids, *Lyguslucorum* and *Adelphocoris* spp. (Hemiptera: Miridae) on *Bt* cotton in northern China. *Crop Prot.* **21 :** 997–1002.

Wu, K. and Guo, Y. 2005. The evolution of cotton pest management practices in China. *Annu. Rev. Entomol.* **50 :** 31–52.

Wolfenbarger L.L., Naranjo S.E., Lundgren J.G., Bitzer R.J., Watrud L.S. 2008. *Bt* Crop Effects on Functional Guilds of Non-Target Arthropods: A Meta-Analysis. PLoS ONE 3(5): e2118. doi:10.1371/journal.pone.0002118.

Yunhe Li, Jörg Romeis, Ping Wang, Yufa Peng, Anthony M. Shelton. 2011. A Comprehensive Assessment of the Effects of *Bt* Cotton on Coleomegilla maculata Demonstrates No Detrimental Effects by Cry1Ac and Cry2Ab. PLOS Published: July 12, 2011 DOI: 10.1371/journal.pone.0022185.

Yang, P., Iles, M., Yan, S. and Jolliffe, F. 2005a. Farmers' knowledge, perceptions and practices in *Bt* cotton in small producer systems in Northern China. *Crop Prot.* **24 :** 229–39.

Zhao, J.H., Ho, P. and Azadi, H. 2011. Benefits of *Bt* cotton counter balanced by secondary pests? Perceptions of ecological change in China. *Environ. Monit. Assess.* **173 :** 985–94.

Zeilinger, A.R., Olson, D.M. and Andow, D.A. 2011. Competition between stink bug and heliothine caterpillar pests on cotton at within-plant spatial scales. *Entomol. Exp. Appl.* **141 :** 59–70.

16

Increasing trend of biopesticides in the cotton production technologies

A.G. SREENIVAS AND G.N. SHREEVANI

Department of Entomology, College of Agriculture, University of Agricultural Sciences, Raichur 584 104

Email: agsreenivas@gmail.com

Two thirds of today's world population depends upon agriculture for livelihood, but nowadays, growth and production of agricultural crops is getting hampered day by day due to insect pests and diseases (Elumalai and Rengasamy, 2012). When farmers see their agricultural crops declining in yield and production, they often expect a dramatic, magical treatment to make them lush, green, and healthy again, so that the productivity increases. As a result, they start using chemical pesticides, disregarding their future effects. The extensive use of these synthetic organic chemicals in the past decades has led to a number of long-term environmental problems (Arora *et al.,* 2012). Keeping all these facts in mind, a very big challenge in the new millennium is to produce more and more food from shrinking per capita arable land, keeping the environment safe and innocuous. By the advent of greener approach of developing and using bio pesticides, the situation is gradually changing but in fact can move far more swiftly in this direction which will be sustainable and eco friendly (Mishra *et al.,* 2015). Although bio-pesticides are slowly replacing the chemical pesticides, a complete global look at the scenario indicates that the farmer and particularly the industries based on them are still in an insecure position in comparison to the chemicals which rule the agriculture.

Scenario of cotton production in India : Over the years, country has achieved significant quantitative increase in cotton production. Till 1970s, country used to import massive quantities of cotton in the range of 8.00 to 9.00 lakh bales/annum. However, after Government launched special schemes like intensive cotton production programmes through successive five-year plans, cotton production received the necessary impetus through increase in area and sowing of hybrid varieties around mid 70s (Rajendran and Jain, 2004). Since then, the country has become self-sufficient in cotton production barring few years in the late 90s and early 20s when large quantities of cotton had to be imported due to lower crop production and increasing cotton requirements of the domestic textile industry (http://cotcorp.gov.in/national-cotton.aspx).

Since launch of **"Technology Mission on Cotton"** by Government of India in February 2000, significant achievements have been made in increasing yield and production through development of high yielding varieties, appropriate transfer of technology, better farm management practices, increased area under cultivation of *Bt* cotton hybrids etc. Introduction of *Bt* cotton has played a pivotal role which brought down more than 50 per cent insecticide usage on cotton and 30 - 40 per cent increase in productivity due to effective pest control and reduction in crop damage (Kranthi, 2012).

Shift of wheel from pesticides to bio pesticides : It is well known that there have been some discoveries in the past which not only have changed the life of man but also had major influence on the globe, and a very well-known chemical pesticide para dichloro diphenyl trichloroethane (DDT) was one of them (West and Campbell, 1946). There are myriads of incidences dealing with DDT poisoning that are already known and some are needed to be further explored (Hill and Robinson, 1945; Dresdend, 1948; Keane, 1972; Tschirley, 1973; Longnecker *et al.,* 1997; Conis, 2010 and Qiu, 2013). DDT was not the only culprit; other categories of synthetic pesticides such as organophosphates (OP), carbamates and pyrethroids were also launched, and by 1980, their impact on pest control and environment was also well recognized (Aktar *et al.*, 2009).

In the eighteenth century and even in the beginning of the nineteenth century, the focus of biological control was to use animals such as birds and entomophagous insects; microbes were not even properly known at that time. The discovery of *Bacillus thuringiensis* (*Bt*) showed a wider aspect of microbe-based biological control (Aronson *et al.,* 1986; Martin and Traverse, 1989; Siegel and Shadduck, 1990; Marrone, 1994; Joung and Cote, 2000). Microbial pest control was a very new concept, and its selective action on pest attracted the concentration of researchers and industrialists equally, and soon the first commercial *Bt* product, Thuricide, was registered in the USA in 1961 (USEPA, 1998). Since then, different sub-species, varieties, and strains of *Bt* have been identified that are effective against a variety of insects (Gonzalez *et al.,* 1982 and Carlton, 1988). In a span of very few years, *Bt* has covered up to 90 per cent of the whole bio pesticide market (Chapple *et al.,* 2000 ; Chattopadhyay *et al.,* 2004 and Romeis *et al.,* 2006), and several *Bt* strains are now registered as bio-pesticides throughout the world (Glare and Callaghan, 2000).

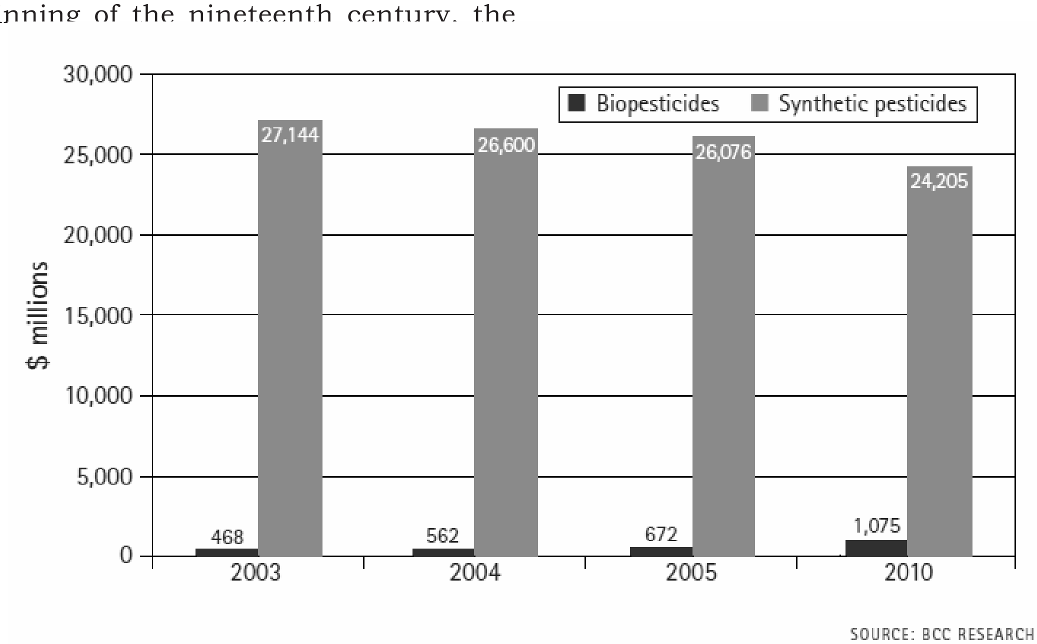

Fig. Global bio pesticides and synthetic pesticides market, 2003–2010

Bio pesticides in world and India : With the increased environmental awareness and the pollution potential and health hazards from many of the conventional pesticides, the demand for nature-based bio-pesticides has been increasing steadily worldwide. The current global organically cultivated agricultural product market is valued at approximately $28 billion. Globally, about 22 million hectares are now organically cultivated. This represents less than 1 per cent of the world's conventional agriculture production and, therefore, a tremendous growth potential for the use of bio-pesticides (Yatin, 2006).

India has vast potential for bio pesticides. However, its adoption by farmers in India needs education for maximizing gains. Bio pesticides represent only 3.59 per cent (as on 2010-11) of the overall pesticide market in India. In India, so far only 12 types of bio-pesticides have been registered under the Insecticide Act, 1968. Neem based pesticides, *Bacillus thuringensis*, NPV and *Trichoderma* are the major bio-pesticides produced and used in India. Whereas more than 190 synthetics are registered for use as chemical pesticides. As of September 2015, there are 436 registered bio pesticide active ingredients and 1401 active bio-pesticide product registrations (http://www2.epa.gov/). Most of the bio pesticides find use in public health, except a few that are used in agriculture wherein, transgenic plants and beneficial organisms are used for pest management in India.

Classes of bio pesticides : Bio-pesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. They include a broad array of microbial pesticides, bio chemicals derived from micro-organisms and other natural sources, and processes involving the genetic modification of plants to express genes encoding insecticidal toxins (Salma *et al.,* 2011).

Bio pesticides fall into three major categories

1. Biochemical pesticides: Naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances that interfere with mating, such as insect sex pheromones, as well as various scented plant extracts that attract insect pests to traps. In 1979, the U.S. EPA registered the first insect pheromone for use in mass trapping of Japanese beetles. In the 1990s, researchers began testing kaolin clay as an insect repellent in organic fruit orchards. It was made commercially available, particularly for use in organic systems, in 1999.

Spinosad 48 SC, a natural insecticide is a mixture of two derived from fermentation technology produced by *Saccharopolyspora spinosa,* a new species of actinomycete. Spinosad 48 SC is selectively active on insect pests belonging to Lepidoptera. An experiment was conducted to evaluate the bio efficacy of Spinosad 48 SC at four dosages. *Viz.,* 25, 50. 75 and 100 g a.i./ha for two seasons. Results indicated that Spinosad 48 SC at higher dosage levels recorded lower leafhopper and aphid population with average whitefly population reduction. Spinosad 48 SC @ 100 g a.i./ ha recorded minimum per cent bollworm incidence and was *on par* with its lower dosage 75 g a.i. /ha treatment. Maximum good opened bolls and minimum bad opened bolls/plant with higher cotton yield was recorded in Spinosad 48 SC at 100 g a.i./ha. Spinosad 48 SC + Chlorpyrifos @ 25+500 g a.i./ ha combination treatment was *on par* in all the parameters to Spinosad 48 SC alone at 100 g a.i./ ha treatment. Spinosad 48 SC has its combination of excellent contact and residual efficacy on target pests and safety to beneficial insects and low quantity of application is required for effective management of cotton bollworm. *Helicoverpa armigera* (Hubner). Spinosad 48 SC fits very well in cotton IPM system under irrigated conditions (Patil *et al.*, 1999.)

Studies conducted by Sreenivas and Patil (2001) revealed that commercial neem products were screened for two seasons against cotton insect pests. Pooled data of two seasons indicated that two neem products namely Rakshak and Limnol @ 5.0 l/ha were as effective as endosulfan 35 EC @ 1050 g a.i / ha in reducing the cotton bollworms damage, but were not effective against cotton leafhoppers. Further, neem products were fairly safe to *Trichogramma* egg parasitoids. The role of *neem* products' integration with egg parasitoids and insecticides was studied and found to be fitting well in insect pest management in cotton. Similarly, laboratory study was conducted by Gupta and Raghuraman (2004) using a control group consisting of *Helicoverpa armigera* that was reared on artificial diet without any *neem* treatment. Different concentrations of *neem* (*Azadirachta indica*) (1500 ppm Godrej Achook, 50 000 ppm Neemazal and 60000 ppm *Neem Jeevan* Triguard) were prepared by serial dilution method and their bioefficacy was studied by an artificial-diet surface incorporation technique. The formulations containing azadirachtin-rich content were highly toxic to *H. armigera*. Both Neemazal and Neem Jeevan Triguard at 0.15 per cent showed the best antifeedant effects (73 %). The juvenomimetic effects against *H. armigera* were also studied. The developmental time was significantly longer for all the azadirachtin-rich formulations compared to the control. Larvae treated with Neemazal and *Neem Jeevan* Triguard required 35.8 and 11.1 per cent additional days, respectively, to reach the pupal stage compared to the control. Azadirachtin caused deformities in the developing larvae, pupae and adults. The most marked morphogenetic effects that appeared were larval pupal intermediates, deformed pupae, and adults with frizzled or curved wings, weak and smaller in size. At 0.025 and 0.05 per cent azadirachtin, inhibition and disruption of moulting were observed; however, larval-pupal intermediates and abnormal pupae were also commonly observed. The larval-pupal intermediates were observed at moderate concentrations (0.075 % of Neemazal and 0.10 per cent of *Neem Jeevan* Triguard) resulting in 18.7 per cent of the larval pupal intermediates. The pupal period was also prolonged, where pupae required 43.5 per cent of additional days to reach the adult stage in both the formulations compared to the control. Pupal weight was also significantly lower compared to the control. The pupae that survived either failed to develop further or if developed into adults, died during eclosion with frizzled or curled wings.

2. Microbial pesticides: consists of a micro organism (*e.g:* a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pests. They offer the advantages of higher selectivity and lower or no toxicity in comparison to conventional chemical pesticides (MacGregor, 2006). These include bio fungicides (*Trichoderma*, *Pseudomonas*, *Bacillus*), bio herbicides (*Phytophthora*), and bio insecticides (*Bt*) (Gupta and Dikshit, 2010). The most widely used microbial pesticides for insects are sub-species and strains of *Bacillus thuringiensis*, or *Bt*. Each strain of this bacterium produces a different mix of proteins and specifically kills one or a few related species of insect larvae. While, some *Bt* ingredients control moth larvae found on plants, other *Bt* ingredients are specific for larvae of flies and mosquitoes.

Experiments involving biological control for insect pests in agriculture date back to 1835, when Agostine Bassi demonstrated that white-muscadine fungus (*Beauveria bassiana*) could be used to cause an infectious disease in silkworm. The first, and still most, widely used biopesticide included spores of the bacteria *Bacillus thuringiensis* (*Bt*). In 1901, *Bt* was isolated from a diseased silkworm by Japanese biologist, Shigetane Ishiwata. Ernst Berliner in Thuringen, Germany, then rediscovered it ten years later in a diseased caterpillar of flour moth. The *Bt* pathogen was classified in 1911 as type species *Bacillus thuringiensis* and remains the most widely used bio pesticide to this day. In the early 1920s, the French began to use *Bt* as a biological insecticide. The first commercially available *Bt* product, Sporeine, appeared in France in 1938. In US, in the 1950s, widespread use of bio pesticides began to take hold as a host of research on *Bt* efficacy was published. In 1973, *Heliothis* NPV was granted exemption from tolerance and the first viral insecticide, Elcar received a label in 1975. In 1977, *Bacillus thuringiensis* var. *israelensis* (toxic to flies) was discovered, and in 1983 the strain *tenebrion is* (toxic to beetles) was found.

Bacterial biopesticides : Bacterial biopesticides are the most common form of microbial pesticides that function in multiple ways. In insects, bacteria disrupt the digestive system by producing endotoxins that are often specific to the particular insect pest (Brien *et al.,* 2009). The members of the genus *Bacillus* are often considered as microbial factories for the production of vast array of biologically active molecules, some of which are potentially inhibitory for fungal growth (Schallmey *et al.*, 2004).

Field study was conducted by Sreenivas and Patil (2001) for two years to evaluate the *Bacillus thuringiensis* commercial products *viz.*, *BT*K 1, *BT*K II, Dipel, Delfin and BARC strain against bollworm. *Helicoverpa armigera* (Hubner) on cotton. The *B. thuringiensis* products were applied four times based on ETL of pest population. Among the various *B. thuringiensis* products, *BT*K II recorded lowest bollworm damage highest GOB, lowest BOB and maximum cotton yield which was *on par* with Dipel 8 L. *Bacillus thuringiensis* products are detrimental to all stages of mulberry silkworm, *Bombyx mori* and mortality was recorded up to 40 days when treated mulberry leaves are fed to worms. Mortality of silkworm was observed in Dipel spray drift at 5 m and 20 m distance with knapsack and power sprayer respectively.

A comparative study of *Bacillus thuringiensis* on cotton bollworms was carried out by Rehman *et al., (*2002). Three *Bacillus thuringiensis* biopesticides were sprayed at their recommended rate against cotton bollworms, which have controlled these pests effectively both in laboratory and field trials. In the lab, CAMB- *Bt* was found the best bio-pesticides giving 100 per cent mortality with in 48 hrs against spotted bollworms. Similarly, Lepinox-*Bt* gave 100 per cent mortality against spotted bollworms. However, it was least effective against American bollworm with less than 60 per cent killing. Comparatively Larvo-*Bt* gave less than 20 per cent mortality against both the insects.

Fungal biopesticides : *Beauveria bassiana* (Balsamo) Vuillemin and *Metarhizium anisopliae* (Metchnikoff) Sorokin are naturally occurring entomopathogenic fungi that infect sucking pests including *Nezara viridula* (L) (green vegetable bug) and *Creontiades* sp. (green and brown mirids) (Gomez and Moscardi, 1998). Fungi have the unique ability to attack insects by penetrating through the cuticle making them ideal for the control of sucking pests. Studies also show that *B. bassiana* is virulent against *Lygus hesperus* Knight (Hemiptera: Miridae), a major pest of alfalfa and cotton in the USA (Noma and Strickler, 2000).

Viral biopesticides : Like bacteria and fungi, viral biopesticides play a significant role in antagonizing pathogens especially bacteria in the form of bacteriophages. Apart from it, viruses are host specific, infecting only one or a few closely related species, thus offering minimal off-target impacts (Cory and Myers, 2003 ; England *et al.,* 2004 ; Raymond *et al.,* 2005 ; Hewson *et al.,* 2011). Baculovirus is the main virus that is commercially used for designing phage pesticides. Since the start of their commercial use, baculoviruses have been tested extensively to assess their safety in order to meet registration requirements (Burges *et al.* 1980; Groner 1986; Ignoffo, 1975). Baculoviruses develop in the nuclei of the host insect cells. When ingested by the host insect, infectious virus particles are liberated internally and become active. Once in the larval gut, the virus's protein overcoat quickly disintegrates, and the viral DNA proceeds to infect digestive cells. Within a few days, the host larvae are unable to digest food and so weaken and die (Yatin, 2006). Baculoviruses are particularly attractive for use as biopesticides due to their high host specificity. Each virus only attacks particular species of insects, and they have been shown to have no negative impacts on plants, mammals, birds, fish, or non target insects (Amico, 2007). Baculoviruses can also cause sudden and severe outbreaks within the host population for complete control of the disease (Sylvar, 2008). Another major advantage of baculoviruses is that in some cases, they can replace and serve as an alternative to the antibiotics and chemical pesticides (Brien *et al.,* 2009).

As of 2010, over 24 baculovirus species have been reported to be registered for use in insect pest management throughout the world (Kabaluk *et al.,* 2010). The market share of baculoviruses is 6 per cent of all microbial pesticides (Quinlan and Gill 2006; Marrone, 2007), and millions of hectares have been treated with registered baculovirus products over the years (Szewczyk *et al.,* 2009; Kabaluk *et al.,* 2010; Moscardi *et al.,* 2011). Despite many years of use and testing against non target organisms, no adverse effects have ever been attributed to baculoviruses (William, 2007).

Sreenivas and Patil (2003) bollworm damage revealed the superiority of HaNPV 500 LE+ edosulfan 35 EC 1050 g a.i application which recorded minimum pest damage and was *on par* with reduced dose of 250 LE + 1050 g. a.i./ha treatment but superior to sole application of HaNPV and untreated control . Maximum number of good opened bolls was registered in HaNPV 500LE + endosulfan 35 EC 1050 g. a.i./ ha which was *on par* with all combinations except lowest dosage of HaNPV 250 LE + endosulfan 35 EC 525 g. a.i./ha. Among the adjuvants screened teepol , jaggery and boric acid each at 0.1 per cent proved better for HaNPV as they recorded significant control and higher seed cotton yield.

List of some commonly available biopesticides

Category of biopesticide	Products common name or trade name	Targets
B. popilliae	Milky spore powder	Japanese beetle grubs
Bacillus sphaericus Serotype H5a5bstrain 2362 ATCC1170	VectoLex	Mosquito larvae
B . thuringiensis subsp. aizawai NB200	Florbac	Moth larvae
B. thuringiensis sub sp *israelensis*	BMP	Mosquito and blackflies
B. thuringiensis sub sp *israelensis* EG2215	Gnatrol , Aquabac	flies, Mosquito
B. thuringiensis sub sp *aizawaidelta* endotoxin in killed *P. fl uorescens*	M-Trak	Colorado potato beetle
B. thuringiensis sub sp *aizawai* GC-91	Agree WG	Plutella
B. thuringiensis sub sp *kurstaki*	Thuricide Forestry Wilbur-Ellis	
	BT 320DipelDeliverBiobit	
	HPForayJavelin WGGreen	
	LightHi-Yield Worm Spray	
	Ferti-LomeBonideBritz	
	*BT*Worm WhipperSecurity	
	Dipel Dust	Lepidopteran larvae
B. thuringiensis sub sp *kurstaki* BMP 123	BMP123	Lepidopteran larvae
B. thuringiensis sub sp *Tenebrionis*	Novodor	Colorado potato beetle
B. thuringiensis sub sp *kurstaki* EG7826	Lepinox WDG	Lepidopteran larvae
B. bassiana 447	Baits Motel Stay- awhile	Ants
B. bassiana ATCC 74040	Naturalis L	Various insects
B. bassiana GHA	Mycotrol ES Mycotrol	Various insects
	OBotanigard 22WPBotaniGard ES	
B. bassiana HF23	balEnce	Housefl y
M. anisopliae F52	Tick-Ex	Ticks and grubs
Paecilomyces fumosoroseus Apopka 97	PFR-97	Whitefl y and thrips
Nosema locustae	Nolo-Bait Semaspore bait	Grasshopper and crickets
Anagrapha falcifera NPV	CLV-LC	Lepidopteran larvae
Cydia pomonella GV	CYD-X	Virus codling moth
Gypsy moth	NPV	Gypchek Gypsy moth
H. zea NPV (previously *Heliothis zea* NPV)	GemStar	Cotton bollworm, tobacco, budworm
Indian meal moth GV (*P.interpunctella* GV)	Fruitguard	Indian meal moth
Mamestra confi gurata NPV (107308)	Virosoft	Bertha armyworm
Spodoptera exigua NPV	Virus Spod-X	Beet armyworm
Saccharomyces cerevisiae	Bull Run	Fly attractant

A study by Pophum *et al.,* (1997) was conducted on *Helicoverpa zea* Nuclear polyhedrosis virus, which was previously registered and commercially produced as a pesticide (Elcar), was genetically improved to control the cotton bollworm, *H. zea.* A significant reduction in the time required for this virus to kill *H. zea* larvae was achieved by inserting a mite gene encoding a potent insect selective neurotoxin gene, *tox34,* into the viral gene encoding ecdysteroid UDP glucosyltransferase. Under the control of an early viral promoter, expression of *tox34* during infection resulted in 50 per cent mortality or paralysis within 40 h after virus treatment. The ability to genetically improve the properties of this virus as a pesticide provides the opportunity to develop a commercially viable product to control this pest species.

Entomogenous nematodes : An experiment conducted by Sreenivas and Patil (2001) to evaluate the efficacy of commercially available green commondos nematode, *Steinernema feltiae* Filipjev during 1994 and 1995 seasons both in the field and laboratory conditions. Study revealed that the nematodes were applied at 45 lakhs per ha when used alone and 50 per cent together with HaNPV or *Bacillus thuringiensis* or endosulfan 35 EC. Per cent bollworm damage revealed lowest in edosulfan 35 EC treatment which was *on par* with nematodes + half dose of endosulfan 35 EC (16.96%) and combined use of all three pathogens *viz.*, nematodes + HaNPV + *Bt* (@ 45 lakhs + 25 LE + 1.01 /ha). Maximum number of good opened bolls and minimum bad opened bolls with highest seed cotton yield was registered in combined use of all three bioagents treatments which was *on par* with sole application of endosulfan 35 EC. Mortality of *H.armigera* under laboratory conditions revealed superiority of combined use of three pathogens which registered 66.67 per cent mortality of early instars. None of the bioagents registered mortality of late instars up to four days.

3. Plant incorporated protectants (PIPs) are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the *Bt* pesticidal protein and introduce the gene into the plant's own genetic material. Then the plant, instead of the *Bt* bacterium, manufactures the substance that destroys the pest. The protein and its genetic material, but not the plant itself. The genes that code for the insecticidal crystal proteins have been successfully transferred into different crop plants including cotton, tomato, brinjal, etc. that lead to significant economic benefits. Due to their high specificity and safety in the environment, *B. thuringiensis* and Cry proteins are efficient, safe, and sustainable alternatives to chemical pesticides for the control of insect pests (Roy *et al.,* 2007; Kumar, 2012).

CONCLUSIONS

Developing countries have huge possibilities for using bio-pesticides as the production can be less expensive and labour is cheap in comparison to developed nations (Roettger and Reinhold, 2003). Also countries like India are vastly dependent upon agriculture for not only feeding their populations but also for the economy which depends majorly on this sector. However, most of the challenges faced for the upliftment of bio-pesticides are fundamental and cosmopolitan. These include the efficacy of the microbial activity, survival of microorganisms, delivery systems, determining host range, and avoiding injury to non-target organisms, consistency, performance in field conditions, economics, government regulations, and confidence among the end users.

REFERENCES

Aktar, M.W., Sengupta, D. and Chowdhury, A., 2009. Impact of pesticides use in agriculture: their benefits and hazards. *Inter.discip.toxicol.*, **2**:1–12.

Amico, V., 2007. Baculovirus in biological control: a guide to natural enemies in North America. http:// www.nysaes.cornell.edu/ent/ biocontrol/pathogen/ baculoviruses.

Aronson, A., Beckman, W. and Dunn, P, 1986. *Bacillus thuringiensis* and related insect pathogens. *Microbiol Rev.*, **50**:1–24.

Arora, N. K., Tewari, S., Singh, S., Lal, N. and Maheshwari, D.K., 2012. PGPR for protection of plant health under saline conditions. *In:* Maheshwari DK (ed) Bacteria in agrobiology: stress management. Springer, Berlin, pp:239–58.

Brien, K.P., Franjevic, S. and Jones, J,2009. Green chemistry and sustainable agriculture: the role of biopesticides, advancing green chemistry. http:// advancinggreenchemistry. org/wp-content/ uploads/Green-Chemand- Sus.-Ag.-the-Role-of-Biopesticides.pdf.

Burges, H.D., Croizier, G. and Huber, J., 1980. A review of safety tests on baculoviruses. *Entomophaga.*, **25 :** 329–40.

Carlton, B.,1988. Development of genetically improved strains of *Bacillus thuringiensis* . *In:* Hedin P, Menn J, Hollingworth R (eds) Biotechnology for crop protection. American Chemical Society, Washington, DC, pp:260–279.

Chapple, A,C., Downer, R.A. and Bateman, R.P., 2000. Theory and practice of microbial insecticide application. *In:* Lacey, L.A. and Kaya, H.A., (eds) Field manual of techniques in invertebrate pathology. Kluwer, Dordrecht, pp:5–37.

Chattopadhyay, A., Bhatnagar, N.B. and Bhatnagar, R., 2004. Bacterial insecticidal toxins. *Crit. Rev. Microbiol.*, **30**: 33–54.

Conis, E., 2010. Debating the health effects of DDT: Thomas Jukes, Charles Wurster and the fate of an environmental pollutant, *Public Health Rep,* **125** : 337–42.

Cory, J.S. and Myers, J, H., 2003. The ecology and evolution of insect baculoviruses. *Annual Rev. Ecol. Evol. Syst.*, **34**:239–72.

Dresdend, D., 1948. Site of action of D. D. T. and cause of death after acute D. D. T. poisoning. *Nature*. **162**:1000–001.

Elumalai, L.K. and Rengasamy, R., 2012. Synergistic effect of seaweed manure and *Bacillus sp* . on growth and biochemical constituents of *Vigna radiata L* ., *J. Biofertil. Biopest.,* **3**:121-28.

England, L.S., Vincent, M.L., Trevors, J.T. and Holmes, S.B., 2004. Extraction, detection and persistence of extracellular DNA in forest litter microcosms. *Mol. Cell. Probes.*, **18** : 313–19.

Glare, T.R. and Callaghan, M., 2000. *Bacillus thuringiensis* : biology, ecology and safety. Wiley, Chichester.

Gomez, D.R. and Moscardi, F., 1998. Laboratory and field studies on the infection of stink bugs, *Nezara viridula*, *Piezodorus guildinii*, and *Euschistus heros* (Hemiptera: Pentatomidae) with *Metarhizium anisopliae* and *Beauveria bassiana In. Brazil J. Invertebr. Pathol.*, **2** :115–20.

Gonzalez, J.Ì., Brown, Â.J., Carlton, Â.C.,1982. Transfer of *Bacillus thuringiensis* plasmids coding for ä-endotoxin among strains of *B. thuringiensis* and *B. cereus* . *Ñroc Natl Acad Sci.,***79** : 6951–55.

Groner, A., 1986. Specificity and safety of baculoviruses. *In:* Granados RR, Federici, B.A (eds) The biology of baculoviruses, vol 2, Practical application for insect control. CRC Press, Boca Raton, pp 177–202.

Gupta, S. and Dikshit, A.K., 2010. Biopesticides: an eco-friendly approach for pest control. *J Biopest.*, **3** :186–88.

Gupta, G. P. and Raghuraman, M., 2004. Utilization of biopesticides in cotton pest management., *In:* Biopesticides for sustainable agriculture: prospects and constraints 2004 pp. 173-91.

Hewson, I., Brown, J.M., Gitlin, S,A. and Doud, D.F., 2011. Nucleopolyhedrovirus detection and distribution in terrestrial, freshwater, and marine habitats of Appledore Island, Gulf of Maine. *Microbial Ecol.*,62:48–57.

Hill, K.R. and Robinson, G., 1945. Fatal D. D. T. poisoning. *Br Med J.* **2 :** 845–47.

http://www2.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides

Ignoffo, C.M., 1975. Evaluation of in vivo specificity of insect viruses. *In:* Summers, M., Engler, R., Falcon, L.A., Vail, P.V., (eds) Baculoviruses for insect pest control. *Amerc. Soc. Microbiol*, Washington, DC, pp 52–57.

Joung, K.C. and, Cote, J.C., 2000. A review of the environmental impacts of the microbial insecticide *Bacillus thuringiensis*. *In:* Agriculture and Agri- Food Canada, Technical Bulletin. No. 29.

Kabaluk, J.T., Svircev, A.M., Goette, M.S. and Woo, S.G., (eds) 2010. The use and regulation of microbial pesticides in representative jurisdictions worldwide. *IOBC Global*, p 99.

Keane, W.T., 1972. Eliminate DDT? Quest for an advantageous benefit: risk ratio. *Sci Total Environ.*, **2** : 141–63.

Kumar, S., 2012. Biopesticides: a need for food and environmental safety. *J. Biofert. Biopest* **3**:1–3.

Kranthi, K. R., 2012. *Bt* Cotton-Questions and Answers, Indian Society for cotton improvement, Mumbai, 2012, pp.71. Available at http: // www. cicr. org. in/ pdf/ *Bt*_ book _ kranthi. pdf.

Longnecker, M.P., Rogan, W.J. and Lucier, G., 1997. The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBS (polychlorinated biphenyls) and an overview of organochlorines in public health. *Annu Rev Public Health.*, **18** : 211–44.

MacGregor, J.T., 2006. Genetic toxicity assessment of microbial pesticides: needs and recommended approaches. *Intl. Assoc. Env. Mutagen. Soc.*,pp :1–17.

Marrone, P.G., 1994. Present and future use of *Bacillus thuringiensis* in integrated pest management systems: an industrial perspective. *Biocon .Sci. Technol.*, **4** : 517–26.

Marrone, P.G., 2007. Barriers to adoption of biological control agents and biological pesticides, CAB reviews: perspectives in agriculture, veterinary science, nutrition and natural resources 2(51). CAB International, Wallingford.

Martin, P.A.W, and Traverse, R.S., 1989. Worldwide abundance and distribution of *Bacillus thuringiensis* isolates. *Appl. Environ. Microbiol.*, **55** : 2437–42.

Mishra , J., Tewari, S., Singh, S. and Arora, N. K. (ed.), 2015. *Plant Microbes Symbiosis: Applied Facets*, 37., © Springer India.

Moscardi, F., de Souza Lobo M., de Castro Batista, M.E., Moscardi, L.M. and Szewczyk, B., 2011. Baculovirus pesticides – present state and future perspectives. *In:* Ahmad I, Ahmad F, Pichtel P (eds) Microbes and microbial technology. Springer, New York, pp: 415–445.

Noma, T. and Strickler, K., 2000. Effects of *Beauveria bassiana* on Lygus *Hesperus* (Hemiptera: Miridae) feeding and oviposition. *Environ Entl.* **29** : 394–402.

Popham, H. J. R., Yonghong , L., Lois, K. and Miller, 1997. Genetic Improvement of *Helicoverpa zea* Nuclear Polyhedrosis Virus as a Biopesticide., *Biol.Cont.*,10(2) : 83–91.

Patil,B.V., Mujibur Rahaman,S., Sreenivas A.G., and Bheemanna. M.,1999. Spinosad 48 SC: An ideal insecticide in cotton IPM. *Pestology*, **23** : 3-6.

Qiu, J., 2013. Organic pollutants poison the roof of the world: accumulation of DDT in Himalayas exceeds that seen in Arctic, *Nature News.*

Quinlan, R.J. and Gill, A., 2006. The world market for microbial biopesticides, overview volume. CPL Business Consultants, Wallingford, p 26.

Raymond, B., Hartley, S.E., Cory, J.S. and Hails, R.S., 2005. The role of food plant and pathogen-induced behavior in the persistence of a nucleopolyhedrovirus. *J. Invert. Patho.*, **88** : 49–57.

Rajendran, T.P. and Jain, K.C., 2004. Achievement in cotton research, published by All India Coordinated Cotton Improvement Project, 2004, pp.104.

Rehman, M., Zafar, A.U., Nasir, I.A. and Riazuddin, S., 2002. Comparative study of *Bacillus thuringiensis* biopesticides against cotton bollworms., **1** :574-76.

Romeis, J., Meissle, M. and Bigler, F., 2006. Transgenic crops expressing *Bacillus thuringiensis* toxins and biological control. *Nat. Biotechnol.,* **24** : 63–71.

Roy, A., Moktan, B. and Sarkar, P.K., 2007. Characteristics of *Bacillus cereus* isolates from legume-based Indian fermented foods. *Food Contr.,* **18** : 1555–64.

Salma, M., Jogen, K. and Ratul, R., 2011. A review on the use of biopesticides in insect pest management., *Intl. J. Sci. Adv. Tech.,* **1** : 169-75.

Schallmey, M., Singh, A. and Ward, O.P., 2004. Developments in the use of *Bacillus* species for industrial production. *Can. J. Microbiol.* **50** : 1–17.

Siegel, J. P. and Shadduck, J.A.,1990. Clearance of *Bacillus sphaericus* and *Bacillus thuringiensis* ssp. Israelensis from mammals. *J. Econ. Entomol.* **83** : 347–55.

Sreenivas A.G. and Patil,B.V., 2001. Role of *neem* products in cotton insect pests management. *J. Cotton Res. Dev.* **15** : 58-62.

Sreenivas A.G. and Patil, B.V., 2001. Evaluation of *Bacillus thuringiensis* (Berliner) from different sources against *Helicoverpa armigera* (Hubner) on cotton and their cross infectivity to silkworm, *Bombyx mori* (L.). *J. Cotton Res. Dev.* **15** : 171-75.

Sreenivas A.G. and Patil, B.V., 2001. Efficacy of Entomogenous nematode, Stienernema feltiae (Filipjev) against H. armigera (Hub.) on cotton. *J. Cotton Res. Dev.* **15** : 257-60

Sreenivas A.G. and Patil, B.V., 2003. Bioefficacy of HaNPV and adjuvants against bollworm, Helicoverpa armigera (Hubner) on cotton. *J. Cotton Res. Dev.* **17** : 62-64.

Sylvar Technologies (2008). Research. http://www.sylvar. ca/content/13636.

Szewczyk, B., Rabalski, L., Krol, E., Sihler, W. and Souza, M., 2009. Baculovirus biopesticides – a safe alternative to chemical protection of plants. *J. Biopesticides.*, **2** : 209–16.

Tschirley, F.H., 1973. Pesticides, relation to environmental quality. *JAMA* **224** : 1157–66.

USEPA, 1998. Re-registration Eligibility Decision (RED), *Bacillus thuringiensis* , USA.

West, T.W. and Campbell, G.A., 1946. DDT, The synthetic insecticide. Chapman and Hall, London.

William, A., 2007. Environmental impact of baculoviruses, FAO.R7299_FTR_anx3. http://www.fao.org/ docs/eims/upload/agrotech/2003/R7299_FTR_anx3.pdf.

Yatin,T., 2006. The biopesticide market for global agricultural use. *Industrial biotechnology*, **2** : 194-208.

17

Disease scenario of cotton and management strategies in India- Recent developments

D MONGA

Central Institute for Cotton Research, Regional Station, Sirsa-125 055

E-mail : dmonga2009@gmail.com

Historical perspectives and changing disease scenario : The cotton disease scenario has shown a continuous change during the past sixty seven years since independence. When mainly indigenous diploid cottons were being grown in fifties, *Fusarium* wilt, root rot, seedling blight, anthracnose and grey mildew were the major problems. With the large scale cultivation of tetraploid upland cotton (*Gossypium hirsutum*), bacterial blight became the major disease to which indigenous cottons were highly resistant. After the introduction of *Bt* cotton hybrids during 2002 onwards and continuous increase in area under these hybrids to more than 90 per cent of total cotton area till date, the disease scenario has also shown some change. The grey mildew, once a serious problem for diploid cottons especially in central India has now become a major problem in *Bt* cotton hybrids. Grey mildew (percent disease intensity) in central zone was recorded on *Bt* cotton hybrids during 2014-15 in Maharashtra in Akola of Vidahrva region (5.6 to 18.2 % and Nanded-3.9 to 30.5%). In south zone it was severe in two states *i.e.* Karnataka (5-35%), and Andhra Pardesh (0-60.0) during the season. Among other important diseases on *Bt* hybrids, Bacterial blight was reported as important disease in central zone in Maharashtra (Vidahrva- 6.5 to 15.4 %; Nanded 3.5 to 29.7 %) and in south zone in Karnataka (5.0-30.0 %) and Andhra Pardesh (0.0-27.5%). *Alternaria* blight was observed serious during 2014-15 season in Gujrat's Saurashtra area (7.0-22.0%) and Maharashtra's Rahuri (4.4-31.6%) and Nanded (2.0-25.1.%) and in south zone states ie Karnataka (15.0-40.0%), Andhra Pardesh (0.0-53.3%) and Tamil Nadu from 0.0 to 11.0%. (Anonymous, 2015).

Fusarium wilt has become less important as upland cotton now occupying more than 90 per cent area is immune to Indian race of the pathogen. *Verticillium* wilt which appeared in Tamil Nadu remained restricted mainly to that state only.

In north India, the leaf curl disease caused by gemini virus and transmitted by white fly *Bemisia tabaci* has become a threat to cotton cultivation due to development of new recombinant strains and introduction of a number of susceptible *Bt* cotton hybrids in north zone.Severe incidence of disease was observed during 2014-15 season in Punjab(Faridkot-35.0-88.0,Bhatinda-12.7-56,Fazilka-17-80 and Muktsar-10-50), Haryana (Hisar-4.5-76.4,Sirsa-0-26.7,Fatehabad-1.6-24.8, Jind-18.8-41.9 and Bhiwani-0-50.1) and Sriganganagar (7.2-56.6). A disease identified as Tabacco Streak Virus (Ilar virus) transmitted by thrips was observed in the transgenic cotton growing region of Southern Maharashtra and Andhra Pardesh. (Sharma *et al.*, 2007). Avoidable losses due to important diseases like cotton leaf curl virus, (53.6%), bacterial leaf blight(20.6%), Alternaria leaf spot (26.6%), grey mildew(29.2%)and Myrothecium leaf spot (29.1%) have been documented (Monga *et. al.,* 2013) Newer chemicals like propiconazole, captan+hexaconazole, tetraconazole and strobilurin compounds (fungicides) and copper hydroxide (bactericides) have been successfully tested for the management of foliar disease of cotton (Monga *et. al.,* 2011) Strategies for the integrated management of diseases causing losses in terms of yield and quality need to be redefined.

Role of bioagents and SAR chemicals in disease management : A field experiment was conducted at Dharwad, Guntur and Coimbatore, consecutively for three years during kharif seasons of 2009 to 2012 to evaluate efficacy of the SAR inducing chemicals *viz.,* Salicylic acid, Isonicotinic acid and *Pseudomonas fluorescens* (Pf) strains against foliar diseases of cotton. Eight treatments, comprising of seed treatment and foliar spray with two strains of *P. fluorescens* (CICR H1a and TNAU) and foliar spray of – Propiconazole, – Carbendazim, – Copper oxy chloride plus Streptocycline, Salicylic acid, Isonicotinic acid and – water spray (Control) were evaluated in randomized block design.

Pooled data revealed that the strains of *P fluorescens* applied as seed treatment and foliar spray and propiconazole spray were significantly superior to other treatments against *Alternaria* leaf spot disease at Guntur and Coimbatore. Both *Pseudomonas* strains along with COC + Streptocycline were statistically on par in managing bacterial blight at Guntur. Carbendazim was best in controlling grey mildew at Dharwad as well as Guntur while *Pseudomonas* strains were also superior at Guntur. Propiconazole (0.1%) and COC + Streptocycline were best followed by SAR chemicals against rust at both the centres. Maximum seed cotton yield of 1806 kg/ha was recorded with COC (0.3%) + Streptocycline (0.01%) followed by carbendazim (1765kg/ha) and isonicotinic acid (1763kg/ha). Based on Benefit Cost ratios, it was concluded that the SAR chemicals and Pf isolates can be a good substitute of fungicides for the management of foliar diseases in cotton crop (Bhattiprolu *et al.,* 2014).

Integrated disease management modules : A new programme under AICCIP was initiated during 2011-2012 where studies on developing integrated disease management modules on important diseases prevailing in a particular state were initiated. While designing the experiments, due emphasis was given on bio based interventions and also the new chemicals screened under AICCIP in addition to existing recommended package and practices prevailing in the states. Initially the experiments were designed for Andhra Pradesh, Tamilnadu and Maharashtra (Marathwada region) and three years studies were completed in 2013-2014. Subsequently new experiments were started in Gujrat, Karnataka and Maharashtra (Vidharva region) during 2014-2015 (Anonymous, 2012, 2013 , 2014 and 2015).

Integrated Management studies of cotton diseases (Alternaria Leaf Blight, Bacterial Blight &Rust) at Guntur, Andhra Pardesh for three years (2011 -2013) showed that maximum IBCR of 1.35 was recorded with ST- *Pseudomonas fluorescens*@ 10g/kg seed, SA– *Trichoderma viride* @ 2.5kg/ha, Foliar spray with kresoxim methyl @ 1ml/l at 60 DAS and captan+hexaconazole (Taqat) 1g/l at 90 DAS for fungal diseases in *Bt* hybrid Jadoo BG II.

Integrated management of cotton diseases (Root rot and Alternaria Leaf Blight) at Coimbatore, Tamilnadu (2012 and 2013) showed that the incremental cost benefit ratio with ST – *Bacillus subtilis* (BSC5-TNAU1) + SA @ 2.5 Kg/ha + Foliar spray with *B. subtilis* (1%) on 60, 90 and 120 DAS using Bunny *Bt* was 1.16 as against farmers practice. Likewise the ICBR with respect to the same module in RCH II Bt was 0.94 in comparison with that of farmers practice.

Integrated Management of *Alternaria* leaf blight (ALB) at Rahuri, Maharashtra (2012 &2013) showed that the seed treatments of bioagent with chemical sprays was found most effective in minimizing the ALB disease intensity by 63.20% with Seed Treatment - PF TNAU1 @ 10g/kg of seed, SA- *T. viride* @ 2.5 kg/ha (TV- TNAU1) in 250 kg of Compost or FYM., Foliar spray with Ergon @ 1ml/L @ 60 DAS and Taqat @ 1.5g/L @ 90 and 120 DAS for fungal diseases in *Bt* hybrid Krishi dhan rakhi.

Based on the studies conducted during 2014-15, at Akola under IDM modules, the seed treatments/soil application of bioagents along with chemical sprays (Seed Treatment – PF CICR @10 g/kg of seed; Soil Application of *Trichoderma viride* @ 2.5 kg /ha TV-TNAU1 and foliar spray with Propiconazol (0.1%) for foliar diseases) were found more effective in minimizing the ALB disease intensity by 67.7 per cent in Bunny *Bt* hybrid. Seed Treatment *Pseudomonas fluorescens* (PF-CICR) @ 10g/kg of seed, soil application *Pseudomonas fluorescens* (PF-CICR) @ 2.5 kg/ha in 250 kg of Compost or FYM and foliar spray with *P. fluorescens* (1%) (PF-CICR) was the best module at Dharwad for the management of seedling mortality and other foliar diseases. Whereas at Junagarh IDM module of seed treatment with *Pseudomonas fluorescens* (PF-CICR) @ 10g/kg seed; soil application with *T.viride* (TV-TNAU) @2.5kg/ha in 250kg of FYM and foliar spray with Ergon @ 1ml/l followed by Taqat @1.5g/l for fungal diseases or COC (0.3%)+ Streptocycline (0.01%) for BLB was best for the reduction of diseases (Alternaria and bacterial blight) and with maximum seed cotton yield.

These studies have indicated that IDM modules using bio based applications in the form of seed treatment/soil application followed by fungicidal interventions can be very fruitful and we therefore need to ensure large scale quality production of such bioagents with the involvement of public/private sector.

New management strategies for cotton leaf curl virus disease : Cotton leaf curl virus disease (CLCuD) earlier known as African leaf curl of cotton was reported for the first time from Nigeria on *Gossypium peruvianum and G. vitifolia* in 1912 by Faquharson. The disease was first reported in India on *G barbadense* at Indian Agricultural Research Institute, New Delhi in 1989. Subsequently it appeared in patches during 1993 around Sriganganagar district of Rajasthan and Ferozepur district of Punjab adjoining to Pakistan border on *G. hirsutum* and spread to entire north Indian cotton zone of around 14 lakh hectares in a short span of 4-5 years. CLCuD is caused by a complex of whitefly (*Bemisia tabaci*) transmitted Begomoviruses having monopartite genome with circular ss DNA associated with satellite (beta and alpha satellite) DNA molecules. Development of resistant/tolerant cultivars, avoidance/eradication of alternate hosts including weeds and whitefly management are the only three effective means of its control.

An experiment with nine interventions *i.e.* buttermilk (the liquid left over after extracting butter from churned yogurt) @ 5 per cent, Cow urine (*Desi* cow) @ 6.6 per cent, *Neem* oil (Azadirachtin-1500ppm) @1 per cent, Mustard oil @ 3 per cent, Kaolin @ 2 per cent, Calcium nitrate @ 0.5 per cent, Potassium nitrate @ 0.5 per cent Paraffin-liquid @ 2 per cent - Kresoxim methyl @ 0.1 per cent, Acephate (chemical control for whitefly) @ 0.4 per cent and Control was conducted for two years (2011-2013) to study their effect on the cotton leaf curl virus disease (CLCuD) and whitefly management. Significantly lower cotton leaf curl virus disease incidence and percent disease intensity (PDI) compared to control was noted in all interventions except acephate and potassium nitrate. The lowest incidence, however, was observed in cow urine treatment followed by kresoxim methyl, calcium nitrate, buttermilk and neem oil. In case of PDI, it was also the lowest in cow urine treatment followed by kresoxim methyl, *neem* oil, calcium nitrate and buttermilk. The cow urine treatment showed significantly superior and highest seed cotton yield as compared to check. The reduction (%) of whitefly in case of neem oil was 31.19 and 17.52 during 2011-2012 and 2012-2013 whereas Calcium nitrate resulted in 10.49 and 12.84 per cent reduction in whitefly population during 2011-2012 and 2012-2013, respectively. Acephate treated plots showed a reduction of 36.26 and 21.69 per cent during two years of testing. Other treatments did not show any clear and consistent trend. Improvement in Uniformity ratio and fiber strength was noted with various interventions whereas fiber length and micronair were not affected significantly. Validation of results of selected interventions was also carried out in poly house and large plots at experimental area of Regional Station and farmer fields (Monga *et al.,* 2015).

A module with ten treatments and control was tested at four locations(Sriganganagar, Faridkot, Hisar and Sirsa) during 2012 and 2013 to study its efficacy in whitefly and CLCuD management. It was observed that module with sprays of Nimbicidine (30DAS), Admire (45DAS), Nimbicidine (60 DAS), *V. Lacani* (75 DAS), Acephate (90DAS) showed maximum reduction of whitefly. The maximum CLCuD reduction (PDI) was observed when Nimbicidine (30DAS), Cofidore (45DAS), Nimbicidine (60 DAS), V. Lacani (75 DAS) were applied followed by the above referred module which showed maximum whitefly reduction.

A new strategy of screening of these hybrids against CLCuD was evolved under AICCIP. Accordingly, four trials (two normal sown released and pre released *Bt* cotton hybrids with 100 entries each and two late sown released and pre released hybrids with 50 entries each) were planted during 2014-15 with standardized screening protocols using susceptible checks at each location. Based on these trials, CLCuD tolerant hybrids were identified. Similarly, three trials with a total of 130 *Bt* cotton hybrids are laid out at five locations (Hisar, Sirsa, Bhatinda, Faridkot and Sriganganagar) for their screening against CLCuD during the current season ie 2015-16.

Future challenges : Cotton leaf curl virus disease, an important problem presently restricted to north zone need to be dealt more seriously in the context of its possibility of shifting to central and south zone. Further due to changed scenario leading to the development of recombinants and breakdown of resistance, new strategies need to be planned. As no sources of absolute resistance are available in the entire germplasm, we need to look beyond that by introgression of resistance from other available sources through inter specific hybridization. The work on development of transgenics using RNAi technology and marker assisted selection is in progress and may go a long way in development of resistance against this important viral disease. Other components of integrated disease management strategy like cultural practices including weed management and vector control using innovative methods need to be pursued vigorously to obtain a holistic approach. Certain other diseases like *Alternaria*, Bacterial blight and grey mildew showing significant appearance in few areas at present shall need development of integrated management modules. A vigil is required on the emerging problems like tobacco streak virus and developing protocols of screening methodologies for identification of resistant sources against them. Another important aspect will be to focus on the disease development and progress vis-a-vis climate changes to understand disease epidemiology and fine tune management strategies.

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REFERENCES

Annonymous, 2012. *AICCIP Annual Report (2011-2012),* All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Annonymous, 2013. *AICCIP Annual Report (2012-2013),* All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Annonymous, 2014. *AICCIP Annual Report (2013-2014),* All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Annonymous, 2015. *AICCIP Annual Report (2014-2015),* All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Bhattiprolu, S.L., Nakkeeran, S., Rao, M.S.L. Chattannavar, S.N., Chakrabarty, P.K. and Monga, D. 2014. Field Evaluation of Systemic Acquired Resistance (SAR) Inducing Chemicals and *Pseudomonas fluorescens* against Foliar Diseases of Cotton. *Cotton Res. Jour.* **6** : 41-45.

Farquharson, C.O. 1912. A report of the mycologist. A report Agric. Deptt. Nigeria. In Siddique MA and Hungus LC (Eds) Cotton growth in Gezira environment. W Haffer and Sons Ltd. Cambridge England. p 106.

Monga, D, Shree Lakshmi, B. and Prakash, A.H. 2013. Crop losses due to important cotton diseases. Technical BulletinNo.1, Published by Head, CICR, Regional Station, Sirsa, Haryana 23p.

Monga, D., Kranthi, K. R., Gopalakrishnan, N. and Mayee, C.D. 2011. Changing scenario of cotton diseases in India-The challenge ahead. Lead paper presented at 5th World Cotton Research Conference held at Mumbai 7-11 November,2011. Paper published in book of papers pp:272-280.

Monga, D., Kumar, R., Solanki, P., and Kayasth, M. 2015. Management of cotton leaf curl virus disease through innovative interventions, *Cotton Research Journal* (personal communication)

Sharma, O.P., Bambawale, O.M., Datar, V.V., Chattannavar, S.N., Jain, R.K., and Singh, Amerika 2007. *Diseases and disorders of cotton in changing scenario. NCIPM Technical Bulletin.* Pp.20.

Status of nematode problems on cotton : An Indian scenario

K. K. VERMA

Department of Nematology, CCS Haryana Agricultural University, Hisar-125 004

Email: kkv1959@gmail.com

Cotton is a major fibre crop of global importance and has high commercial value. It is grown in temperate and tropical regions of more than 70 countries and is grown in all types of soil except pure sand, saline and water logged soils. Specific areas of its production include India, China, US, Pakistan, Uzbekistan, Egypt, Turkey, Australia, Greece etc. Cotton, popularly known as **"White Gold"** is an important crop in world agriculture and is used by about 75 per cent of world's population for textile purposes because its fiber is used universally as a textile raw material. In addition to clothing, cotton seed is a major source of vegetable oil and cotton cake is a rich source of high quality protein for stock feed. In India, it is important cash and commercial crop valued for its fibre and vegetable oil and thus earning valuable foreign exchange by providing employment to millions of people, hence plays a significant role in national economy.

India continued to maintain the largest area under cotton and is second largest producer of cotton next to china with 35.3 per cent and 24.0 per cent of world cotton area and production, respectively. India also sustained the position of being the second largest consumer and exporter of cotton. In India, the major cotton growing states are Punjab, Haryana, Maharashtra, Madhya Pradesh, Gujarat, Tamil Nadu, Karnataka etc. and the area under cotton cultivation during 2013-2014 was 11.7 million hectares with production around 29 million bales of 170 kg. As regards cotton production, Gujarat is the leading cotton producing state with 106.8 lakh bales. The state of Haryana had cotton in an area of 5.57 lakh hectares with production of 20 lakh bales of 170 kg during 2013-2014 (All India Coordinated Cotton Improvement Project – Annual Report, 2013-2014).

The cultivation of cotton falls into three main groups *viz.*, Egyptian or American Egyptian type, the long staple cotton, *i.e.*, *Gossypium barbadense* (allotetraploid), American and African upland medium staple cotton, *i.e.*, *G. hirsutum* (allotetraploid) and Asiatic old world short staple cotton, *i.e.*, *G. arboreum* (diploid) and *G. herbaceum* (diploid). *G. hirsutum* accounts for over 80 per cent of global cotton production. But, during past few years, it has been observed that traditional cotton cultivation of non *Bt* has given way to cultivation of *Bt* cotton hybrids.

The successful raising of this crop is hampered by the attack of number of insect pests and diseases. During recent past, phytoparasitic nematodes, which not only cause diseases by themselves directly but also aggravate the disease caused by fungi, have assumed significance in limiting the production of cotton in many cotton growing areas of the country. Because cotton is grown as a cash crop, it is often grown in monoculture system that favours the development of a nematode community that is dominated by one or a few species of plant parasitic nematodes. The important nematode pests of cotton include root-knot nematode (*Meloidogyne incognita*), reniform nematode (*Rotylenchulus reniformis*), lance nematode

(*Hoplolaimus* spp.), sting nematode (*Belonolaimus longicaudatus*) and a few other nematodes of minor importance such as lesion nematode (*Pratylenchus* spp) and stubby root nematode (*Trichodorus christiei*) (Edward *et al.*, 1993). Root-knot nematodes are major problem in many cotton growing areas of India while reniform nematode has regional importance.

Economic importance of plant parasitic nematodes in cotton : The annual yield loss in cotton due to phytoparasitic nematodes on worldwide basis is reported to be 10.7 per cent (Sasser and Freckman, 1987). Among these parasites, the root-knot nematode, *Meloidogyne incognita* is a major yield limiting factor in many countries including India. Davis and May, 2005, recorded the yield suppression in cotton which ranged from 18.0-47.3 per cent in 2002 and from 8.5-35 per cent in 2003 by the southern root-knot nematode.. Similarly, a loss of 17.0 per cent in cotton has been attributed to root-knot nematodes alone in Brazil (Sasser, 1979). Equally important was the reniform nematode. Even as high as 40-60 and 9.5-17.4 % avoidable yield losses were estimated after application of nematicides in Egypt and India, respectively, due to *Rotylenchulus reniformis* (Oteifa, 1970, Palanisamy and Balasubramanian, 1983) while Robinson (2007) estimated annual loss to U.S. cotton crop to be $ 130 million and stated that this nematode has replaced the root-knot nematode as the major nematode of cotton in few US states. The avoidable losses in cotton yield due to root-knot nematode (*Meloidogyne incognita*) under field conditions in Haryana ranged from 16.8 to 20.0 per cent (Jain *et al.*, 2000).

ROOT KNOT NEMATODE (*MELOIDOGYNE* SPP)

A. Distribution : : Among various species of root-knot nematodes, *Meloidogyne acronea and Meloidogyne incognita* are known to parasitize cotton. However, *M.incognita* (Kofoid and White, 1919) Chitwood, 1949, is the only species which is of consequences to the cotton throughout India. It is worldwide in its distribution from nearly all cotton growing areas especially where soils are coarsely textured (Starr et al., 1993). *M. acronea* has so far been found only in some areas of South Africa. The earliest report of root-knot nematode on cotton was from USA (Atkinson, 1989). However, in India the first report of its occurrence on cotton was by Luthra and Vasudeva (1939) from Punjab followed by Thirumalachar (1946). Besides India, it has also been reported from Taiwan (Tu *et al.*, 1972); Pakistan (Tanveer and Haq, 1975); Egypt (Ibrahim *et al.*, 1979); USSR (Khurramov, 1982); Brazil (Lordello *et al.*, 1984); South Africa (Wyk *et al.*, 1987); USA (Martin *et al.*, 1994); China (Yang, *et al.*, 1992), Kenya (Karuri *et al.*, 2010) and from many other countries.

Prasad (1960) observed *M.incognita* on cotton at IARI, New Delhi, Abu Bucker and Seshadri (1968) reported it, attacking cotton from Tamil Nadu, Darekar *et al*. (1992) from Maharashtra, Patel (1984) from Gujarat reported *M.incognita and M.javanica* attacking cotton. Sakhuja *et al.* (1986) reported it from Punjab and race 4 of *M.incognita* infecting cotton in Sirsa district of Haryana was reported first time from India and later on by others (Bajaj *et al.,* 1986; Vats *et al.,*1999, Verma and Jain, 1999). However, presence of race 3 of *M.incognita* equally capable of damaging cotton has been reported from Tamil Nadu and Karnataka (Krishnappa, 1985). The frequency of occurrence of root-knot nematode (*Meloidogyne incognita* race 4) in major cotton growing areas of Haryana was however high (Vats *et al.*, 1999).

B. Symptoms : The foliar symptoms of root-knot nematode attack on cotton are not very diagnostic. Infestation results in uneven, pale, stunted and sick crop. The general symptoms of damage include dwarfing, chlorosis and temporary wilting and a general unthrifty appearance giving the look of nutritional deficiency symptoms. High population density of the nematode at sowing can kill the plants at seedling stage. Cotton is a fairly drought resistant crop by virtue of its long tap root which may reach depths of more than one meter and any damage to this tap root can severely restrict the uptake of water and nutrients, leading to loss of vigour in rest of the plant. Root-knot nematodes attack both tap and lateral roots and leads to formation of galls/knots thereby causing disruption in meristematic zone, which may lead to slowing down or even complete cessation of tap root growth depending upon the initial nematode population in the soil. However, galls on cotton are not as big and numerous as on other susceptible crops like vegetables.

C. Life history/cycle : The life cycle of *M.incognita* is slightly prolonged on cotton when compared to other hosts. The second stage juveniles of root-knot nematode penetrate the roots usually in first 2 cms of root tip and thereafter, they migrate to stelar region. The comparative penetration of *Meloidogyne incognita* in cotton and tomato roots showed 11.3 and 17.2 per cent larval penetration respectively. One generation was completed in 30 days on tomato compared to 32 days on cotton (Rai and Jain, 1989). The life cycle lasts for 33-38 days at 25$^{\text{æ\%}}$ C on *G. barbadense* and for 32 days on *G. hirsutum* (Rai and Jain, 1989).

The pathogenicity of *M.incognita* on cotton revealed that there was significant decrease in plant growth characters at and above one j_2/g soil in non *Bt* cotton (Rai and Jain, 1989) and *Bt* cotton (Chawla, 2015). Further, the reproduction factor (Rf) of *M.incognita* infecting cotton under different soil textures showed maximum Rf value under sand while clay and clay loam soils were least favoured in American cotton (Verma, 1997) as well as in *Bt* cotton (Chawla, 2015). Histopathological changes in cotton roots due to the feeding of *M.incognita* showed that nematode feed on xylem tissue and giant cells were formed in metaxylem. Nematodes were observed lying parallel to stellar region forming multinucleate giant cells with dense cytoplasm (Rai and Jain,1989).

D. Disease complexes : Besides, inflicting direct damage to the plants, root-knot nematodes interact with other micro-organisms such as fungi, bacteria, viruses etc. and thus form disease complexes as phytophagous nematodes are part of soil microfauna like other organisms. In all these interactions, there is greater incidence of wilt or seedling disease with greater yield suppression when cotton is exposed to multiple pathogens than when only a single pathogen is present. Interaction of *M.incognita* with root-rot fungi *Rhizoctonia solani* revealed that concomitant occurrence of both the pathogens led to higher damage to cotton plants as compared to their individual effect. However, maximum damage was recorded when *M.incognita* was inoculated one week prior to *R.solani* in cotton (Verma, 1997). However, when fungus was inoculated one week before nematode, the nematode penetration was restricted upto cortical region. Carter, 1975 concluded that root-knot nematodes were debilitating parasites which weakened the plants and made it more susceptible to attack by *Rhizoctonia* spp. The posterior end of the nematode body was seen out of the epidermis and fungus presence was seen in the form of sclerotia in the cortical tissue (Tekchand *et al.*, 1992). The severity and incidence of wilt of cotton due to *Fusarium oxysporum* f.sp. *vasinfectum* has also been found to increase in presence of *M.incognita*.

E. Nematode management:

I. Chemical methods: Basically, two types of chemicals *viz.,* fumigants and non-fumigants have been used. Soil fumigation with ethylene dibromide, dichloropropene-dichloropropane (DD) and dibromochloropropane (DBCP) proved effective but, DBCP was most promising. However, due to their prohibitive cost, difficulty in application methods, environmental and toxic hazards, their use has been banned in most of the countries including India. Thereafter, non fumigant (non volatile) chemicals were begun to be used for controlling phytonematodes infecting cotton. These chemicals mainly belong to carbamates (aldicarb and carbofuran) and organophosphates (phorate, phenamiphos etc.) group. In Punjab, application of carbofuran @ 1 kg a.i./ha at sowing followed by additional dose of 2 kg a.i./ha 50 days thereafter led to 41 per cent higher cotton yield in root knot nematode affected fields (Sakhuja *et al.,* 1987). In order to use the chemical pesticides, judiciously, seed treatment with systemic nematicides has been found to be an effective proposition, which gives protection for 3-4 weeks thereby providing healthy start to the plant. Seed soaking treatment with monocrotophos or carbosulfan each @ 2000 ppm for two hours or use of neem based pesticides *viz.,* Achook, Nimbicidine etc. @ 1, 2 and 4 per cent have shown promising results against *M.incognita* infecting cotton (Vats *et al.,*1997 and 1998) or a novel nematicide, abamectin @ 100g/ 100 kg seed (Monfort *et al.,* 2006). It has been observed that carbamates like aldicarb and carbofuran gave better results than organophosphatic compounds like phorate and disulfoton in controlling nematodes attacking cotton (Kumar and Agarwal, 1985).

II. Cultural methods : Harnessing of solar energy in northern part of India, where maximum temperature many a times, go as high as 48^{o}C, can help in controlling these noxious soil borne pathogens. Deep summer ploughing of nematode infested fields not only leads to disturbance and instability in nematode community but also causes mortality by exposing the nematodes to solar heat and desiccation and hence reduction in their initial population.

Azadirachta indica leaves used 20 g/kg soil proved effective in terms of minimum galling (16.7 per plant) compared to 118.3 per plant in untreated check. Further, of the various organic manures *viz.,* neem cake, poultry manure, spent compost, FYM and biogas slurry, proved best in improving growth parameters of cotton (Vats *et al.*, 1998, Verma and Jain, 2001). The crop rotations with wheat, barley and oat and also corn and soybean have shown promising results in containing the buildup of root-knot nematode population (Singh *et al.*, 1998, Koenning and Edmisten, 2008).

III. Biological control: Soil application or seed treatment with the number of micro-organisms have been found effective to suppress root-knot nematode infestations in cotton. Various bio agents like oviparasitic fungi, *Paecilomyces lilacinus* and rhizospheric bacteria have been investigated for controlling *M.incognita* infecting cotton. *Azotobacter chroococcum* used as seed dressing treatment method in cotton in *M.incognita* infested soil (Lakshminaryanan *et al.*, 1995) and *Pseudomonas fluorescens* (Timper *et al.,* 2009) mitigated the adverse effects of nematode infection by reducing galling and egg mass production. *Gluconacetobacter diazotrophicus* st. 35-47 (rhizobacteria) used as seed treatment, accounted for 35-47 per cent higher cotton yield in *M.incognita* infested fields (Bansal *et al.,* 2005). This practice has been included as a recommendation for adoption by the farmers in the Package of Practices of *kharif* crops in Haryana. Further, use of vesicular arbuscular mycorrhiza (VAM) fungi (*Glomus fasciculatum*) when applied in *M.incognita* infested soil was effective in increasing plant growth and reducing nematode galling and multiplication (Verma and Jain, 2004). Even a complex of *M. incognita* and root rot fungus, *R. bataticola* was managed successfully using *Trichoderma viride* (Verma, 2011) while Verma and Nandal, 2009 observed reduction in root knot nematode population on cotton using *T. viride* and 50 kg P/ha.

IV. Host plant resistance : Quite a good number of genotypes have been screened by various workers for resistance against *M.incognita*. But, so far no promising genotypes, which could be used for transferring resistance into commercially cultivated type is yet available. However, the cotton variety Auburn 623 has been found to possess a high level of tolerance to root-knot nematode races. Fa LSS and Arkot 9111 have exhibited resistance against *M.incognita* (Dube *et al.*, 1988, Bourland and Jones, 2005). As far as *Bt* cotton is concerned, high degree of susceptibility to root-knot nematode has been reported in all hybrids screened (Verma *et al.,* 2011, Chawla, 2015).

V. Integrated management : For the management of this nematode, Verma *et al.,* (2011) recorded highest increase in *Bt* cotton yield (39.5%) over check and significantly lowest final nematode population in treatment combination of *Gluconacetobacter diazotrophicus* strain 35-47 @ 50 ml/5kg seed and carbofuran @ 1.0 kg a.i./ha as soil application followed by 29.3 per cent yield increase over check in seed treatment with carbosulfan (3.0%) w/w + soil application of carbofuran @ 1.0 kg a.i./ha. Seed dressing treatment with carbosulfan (3.0%) (w/w) alone or with soil application of sebufos @ 1.0 kg a.i./ha at sowing proved effective (Vats *et al.*, 2000). Similarly, Chawla, 2015, observed maximum growth of *Bt* cotton plants and minimum number of eggs and final nematode population in soil treatment with either carbofuran or neem cake + seed coating with carbosulfan.

RENIFORM NEMATODE (*ROTYLENCHULUS RENIFORMIS*)

A. Distribution : This nematode was first observed on the roots of cotton in Baton Rouge, Lousiana (Smith and Taylor, 1941). This is the only species of this nematode to cause economic losses in cotton. It is primarily an inhabitant of tropical and subtropical areas including U.S., (Jones *et al.*, 1959), Egypt (Oteifa, 1970) and India (Varaprasad, 1986; Abu Bucker and Seshadri, 1968). Das and Gaur, 2009 have recently reported high frequency of occurrence of this nematode from Punjab (56.5%), U.P. (42.3%) and Haryana (30.0%). Unlike *M. incognita*, *R. reniformis* is favoured by fine textured soils with a relatively high content of silt or clay (Robinson *et al.*, 1987). In addition to all types of cotton, wide spread occurrence of the nematode was reported in Bt cotton hybrids (Banu, 2009).

B. Symptoms : The nematode causes dwarfing, chlorosis, premature decay and loss of secondary roots and plant mortality. Injury to cotton becomes evident with reduction in emergence of seedlings. The roots of such plants are smaller, fewer and sometimes show browning. Affected plants bear lesser and smaller bolls. There is delay in maturity, a reduction in size of boll and lint percentage, plant growth, seed index and fibre micronaire value (Jones *et al.*, 1959). Stunted patches in fields having pale greenish leaves occur due to the infestation of this nematode in gardenland cotton in Tamil Nadu. Patel *et al.*, 1996 observed an initial inoculum level of 1000 nematodes/plant and above to be pathogenic on cotton.

C. Life history/Cycle: Two races (A and B) of *R. reniformis* have been reported from India, out of which only race A infects cotton (Dasgupta and Seshadri, 1971). The first stage juvenile moults in the egg and comes out as second stage juvenile. The second, third and fourth stage do not feed. After fourth moult, the immature females penetrate the roots and become reniform (Kidney shaped) in five days. The nematode shows no specificity to the age of plants roots but they prefer succulent roots on which they feed close to the root tip. They feed on phloem tissues and cause necrosis of phloem and its parenchyma. Damage to epidermal and parenchyma is observed near site of infection and feeding is limited. Males also penetrate but do not feed. It took 17-23 days for the completion of one life cycle on cotton (Birchfield, 1962). Life table studies of this nematode revealed that the approximate generation time was 25-45 days. Life cycle duration in *Bt* cotton hybrids and their non transgenic parents was found to be similar (Banu, 2009)

D. Disease complexes: The first indication of the association of *R. reniformis* with *Fusarium* wilt of cotton was observed as early as 1940. This nematode forms disease complexes with *F. oxysporum f. sp. vasinfectum*, *Verticillium dahliae* and with several seedling disease pathogens in which this nematode increases the incidence and severity of seedling disease on cotton (Brodie and Cooper, 1964). Studies on the interaction between *R. reniformis* and *R. bataticola* (virulent and avirulent strains) revealed that both strains of the fungi were equally effective in causing seedling rot of cotton in the presence of this nematode (Patel *et al.*, 2004)

E. Nematode management:

I. Chemical methods: Soil application of carbofuran @ 0.5 kg/ha gave good results against reniform namatode in Brazil. Its population was significantly reduced by seed treatment with carbofuran @ 2.0 per cent (w/w) coupled with soil application of either carbofuran, phorate, phenamiphos or carbosulfan each @ 1.0 kg/ha which gave maximum reduction in nematode population at 30 days after germination with significantly higher cotton yield over control (Patel *et al.*, 1996). Soil application of FYM @ 25t/ha together with carbofuran @ 1.0 kg/ha managed reniform nematode effectively and increased seed cotton yield. Robinson *et al.*, 2002, had reported that due to the depth of distribution of this nematode in some soils, yield response to fumigation can be improved by deeper placement of 1,3-dichloropropene.

II. Cultural control: Crop rotation has been reported to be effective in suppressing densities of *R. reniformis* despite the nematode's wide host range. Although crop rotation with non-host crops such as corn and soybean are effective in reducing population and damage incurred by this nematode, rotation with these crops are often economically prohibitive (Davis *et al.*, 2003). A number of non-host crops are known for this nematode (Varaprasad *et al.,* 1986) but their suitability with reference to the biotype existing in a particular locality and economic considerations remains to be ascertained. Mustard and Sesamum, in cropping sequence, reduce populations in Northern India. *Crotolaria juncea* grown as antagonistic crop also suppressed this nematode (Marla *et al.*, 2008)

III. Biological control: Successful suppression of the nematode on cotton by nematophagous, *Pochonia chlamydosporia* was reported by Wang *et al.,* 2005 under green house conditions. Seed and soil application with *Pseudomonas fluorescens* reduced the nematode population to the tune of 63.5 per cent. Similarly, a complex of this nematode with root rot fungus was managed successfully by seed and soil treatment of *T.viride* and *P. fluorescens* (Sivakumar, 2009).

IV. Host plant resistance: Use of cultivars resistant to reniform nematode would become a major component of nematode management program in cotton. High level of résistance to this nematode has been found in *G. arboreum* Nanking CB 1402, *G. barbadense* Texas 110, *G. somalense* and *G. stocksii* (Carter, 1981).

LANCE NEMATODE (*HOPLOLAIMUS* SPP) : Five species of lance nematode *viz., H. columbus*, *H. galeatus, H. indicus*, *H. seinhorsti* and *H. aegypti* have been reported to be pathogenic to cotton. In India, *H. indicus* and *H. seinhorsti* were reported by Abu Bucker and Seshadri, 1968 and Verma and Jain, 1999. Field studies in US showed that *H. columbus* could reduce cotton yields upto 19.0 per cent (Noe and Imbriani, 1986). Heavily infested cotton manifests severe stunting, yellowing and almost complete defoliation in *H. galeatus* infestation. All species exhibit both endoparasitic and ectoparasitic feeding habits. The nematodes start feeding on young tap roots of cotton immediately after seedling emergence (Brodie and Cooper, 1964). Cavities are formed on the root cortex due to destruction of cells. The nematodes also penetrate epidermis but do not cause extensive damage as they do in cortex. Tyloses are formed in the affected xylem resulting in plugging of the xylem elements (Lewis *et al,* 1976). The life cycle of *H. indicus* from egg to egg is completed at 27-36 days at a temperature of 28 to 32* C. Hussey (1977) reported control of lance nematode in the southern US by aldicarb or DBCP treatment and or sub soiling to a depth of 5 cm which resulted in deeper penetration by cotton roots.

Few other nematodes such as sting nematode (*Belonolaimus longicaudatus*), lesion nematode (*Pratylenchus* spp) and stubby root nematode (*Trichodorus christiei*) are of minor importance and hence are not covered under this chapter.

Futuristic approaches : Besides root-knot nematodes, populations of other nematodes is also recorded from some areas. Hence, there is need to carry out intensive surveys for recording other economically important phytonematodes associated with cotton. During recent times, the cotton cultivation has boosted due to introduction of *Bt* cotton hybrids which replaced conventional non *Bt* cultivars at national and state level, so the research work involving *Bt* cotton becomes necessary as all the previous work was conducted on non *Bt* varieties. Except some preliminary work on *Bt* cotton, the systematic and in-depth research on *Bt* cotton was necessitated as now the cotton production and profitability has increased by adoption of *Bt* cotton Other points of future thrusts can be:

- Carry out studies on host parasite relationships.
- Carry out studies on nematode interactions with other co-habiting microorganisms.
- Intensive survey on nematodes on *Bt* cotton in India has to be carried out.
- Screening of transgenic plants to nematodes.
- Identification of resistance genes to reniform and root-knot nematode in cotton.
- Conduct studies on INM in cotton.

REFERENCES

Abu Bucker, A.H. and Seshadri, A.R.1968. Report on a survey of nematode parasites associated with cotton in Madras State. *Indian Journal of Agricultural Sci*ence **35**: 470-76.

Anonymous, 2014. Annual Report (2013-2014), All India Coordinated Cotton Improvement Project., CICR, Nagpur, pp. 1-5.

Atkinson, G.F. 1989. Alabama Polytech. Institute Agricultural Experimental Station Bulletin **9**.

Bajaj, H.K., Jain, R.K. and Gupta, D.C. 1986. Races of root knot nematode, *Meloidogyne incognita* prevalent in Haryana. *HAU Jour. Res.* **16:** 399-400.

Banu, J.G. 2009. Plant parasitic nematodes associated with *Bt* cotton. In Proc. National Symposium on "*Bt* Cotton: Opportunities and prospects" held at CICR, Nagpur from Nov., 17-19, 2009, pp. 100.

Bansal, R.K., Dahiya, R.S., Narula, N. and Jain, R.K. 2005. Management of *Meloidogyne incognita* in cotton using strains of the bacterium, *Gluconacetobacter diazotrophicus*. *Nematologia Mediterranea* **33**: 101-05.

Birchfield, W. 1962. Host-parasite relationship of *Rotylenchulus reniformis* on *Gossypium hirsutum*. *Phytopathology* **52**: 862-66.

Bourland, F.M and Jones, D.C. 2005. Registration of Arkot 9111 germplasm line of cotton. *Crop Science* **45**: 2127-28.

Brodie, B.B. and Cooper, W.E. 1964. Relation of parasitic nematodes to post-emergence damping-off of cotton. *Phytopathology* **54**: 1023-27.

Carter, W.W. 1975. Effects of soil texture on the interaction between *Rhizoctonia solani* and *Meloidogyne incognita* on cotton seedlings. *Jour. Nematology* **7**: 234-36.

Carter, W.W. 1981. Resistance and resistant reaction of *Gossypium arboretum* to the reniform nematode, *Rotylenchulus reniformis*. *Jour. Nematology* **13**: 368-74.

Chawla, L.K. 2015. Pathogenicity and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood on *Bt* cotton. *M.Sc. Thesis,* CCS HAU, Hisar.

Darekar, K.S., Shelke, S.S. and Mhase, N.L. 1992. Plant nematodes associated with cotton in Maharashtra state, India. *Curr.Nematology* **3 :** 97-98.

Das, D.K. and Gaur, H.S. 2009. Distribution and abundance of *Rotylenchulus reniformis* in cotton growing areas in North India. *Indian Jour. Nematology* **39**: 98-103.

Dasgupta, D.R. and Seshadri, A.R. 1971. Races of the reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira 1940. *Indian Jour. Nematology* **1**: 21-24.

Davis, R.F. and May, O.L. 2005. Relationship between yield potential and percentage yield suppression caused by the southern root knot nematode in cotton. *Crop Sci.* **45 :** 2312-17.

Davis, R.F., Koenning, S.R., Kemerait, C., Cummings, D. and Shurley, W.D. (2003). *Rotylenchulus reniformis* management in cotton with crop rotation. *Jour. Nematology* **35**: 58-64.

Dube,V.P., Charaya, M.U. and Pal, Madan 1988. Screening of some cultivars of cotton against root-knot caused by *Meloidogyne incognita* var. *acrita. Indian Phytopath.* **41**: 132-33.

Edward, J.C., Sharma, N.N. and Tripathi, S.C. 1993. Plant parasitic nematodes of cotton in India. *Jour. Ind. Soc. Cotton Improve.***18** : 5-19.

Hussey, R.S. 1977. Effect of subsoiling and nematicides on *Hoplolaimus columbus* and cotton yields. *Jour. Nematology* **9**: 83-86.

Ibrahim, I.K.A., Khalil, H.A.A. and Rezk, M.A. 1979. Root-knot nematode on cotton in northern Egypt. *Jour. Nematology* **11** : 293-317.

Jain, R.K., Singh, J. and Vats, R. 2000. Avoidable yield losses in cotton (*Gossypium hirsutum*) due to *Meloidogyne incognita* race-4. *Indian. Jour. Nematology* **30**: 90-91.

Jones, J.E., Newson, L.D. and Finley, E.L. 1959. Effect of the reniform nematode on yield, plant characters and fibre qualities of cotton. *Agron. Jour.* **51**: 353-56.

Karuri, H. W., Amata, R., Amugune, N. and Waturu, C. 2010. Occurrence and distribution of soil nematodes in cotton production areas of Kenya. *African Jour. Agricul. Res.* **5**: 1889-96.

Khurramov, S.K. 1982. Parasitic nematodes in Southern Uzbekistan. *Uzbeskii Biologicheskii Zhurnal* **2** : 43-50.

Koenning, S.R. and Edmisten, K.L. 2008. Rotation with corn and soybean for management of *Meloidogyne incognita* in cotton. *Jour. Nematology* **40**: 258-65.

Krishnappa, K. 1985. In "An Advanced Treatise on *Meloidogyne* volume. I. Biology and Control" (J.N. Sasser and C.C. Carter, eds.) Deptt. of Plant Pathology and U.S.Agency for International Development, N.C. U.S.A. pp. 379-98.

Kumar, K. and Agarwal, R.A. 1985. Effect of systemic granular insecticides on nematodes of cotton. *Pesticides* **19**: 140-43.

Lakshminaryanan, K., Jain, R.K., Bansal, R.K. and Anand, R.C. 1995. Antagonistic effect of *Azotobacter chroococcum* inoculation on the root-knot disease of cotton. Paper presented in *"16th Annual conference of Association of Microbiologists of India"*, held at CCS HAU, Hisar, November, 8-10, 1995. pp 125-26.

Lewis, S.A., Smith, F.H., and Powell, W.M. 1976. Host parasite relations of *Hoplolaimus columbus* on cotton and soybean. *Jour. Nematology* **8**: 264-69.

Luthra, J.C. and Vasudeva, R.S. 1939. The root-knot disease of cotton. *Curr. Sci.* **8**: 511.

Marla, S.R., Huettel, R. N. and Mosjidis, J. 2008. Evaluation of *Crotolaria juncea* populations as hosts and antagonistic crops to manage

Meloidogyne incognita and *Rotylenchulus reniformis*. *Nematropica* **38** : 155-62.

Martin, S.B., Meeler, J.D., Saunders, J.S. and Jones, W.L. 1994. A survey of South Carolina cotton fields for plant parasitic nematodes. *Plant Disease*. **78**: 787-89.

Montfort, W.S., Kirkpatrick, T.L., Long, D.L. and Rideout, S. 2006. Efficacy of a novel nematicidal seed treatment against *Meloidogyne incognita* on cotton. *Jour. Nematology* **38**: 245-49.

Noe, J.P. and Imbriani, J.L. 1986. *Jour. Nematology* **18**: 624.

Oteifa, B.A. 1970. The reniform nematode problem of Egyptian cotton production. *Journal Parasitology* ***56:*** 255

Palanisamy, S. and Balasubramanian, S. 1983. Assessment of avoidable yield loss in cotton (*Gossypium barbadense* L.) by fumigation with metham sodium. *Nematologia Mediterranea* **11**: 201

Patel, D.J. 1984. Nematode Problems in Gujarat. Paper Presented for panel discussion on Nematological Problems of Economic Importance in North Zone held at HAU, Hisar; September, 20-21, 1987.

Patel, D.J., Patel, M.B., Patel, B.A., Patel, N.B. and Patel, R.R. 1996. Nematode problems of cotton and their management in India. In:Proc. *National Seminar on Centenary of cotton in India*, Gujarat Agricultural University, Surat, pp. 40-51

Patel, R.R., Patel, B.A., and Thakar, N.A. 2004. Role of reniform nematode, *Rotylenchulus reniformis* in the incidence of root rot, *Rhizoctonia bataticola* on cotton. *Ind. Jour. Nematology* **34**:19-21.

Prasad, S.K. 1960. Plant parasitic nematodes observed at the Indian Agricultural Research Institute farm. *Jour. Entomology* **22**: 127-28.

Rai, B.S. and Jain, R.K. 1989. Studies on biology, histopathology and reaction of cotton genotypes to root knot nematode (*Meloidogyne incognita*). Paper presented at National Seminar on *Futuristic Approaches in Cotton Improvement*. Feb., 24-28, 1989 held at HAU, Hisar, pp. 61

Robinson, A.F. 2007. Reniform in US cotton: when, where, why and some remedies. *Ann. Rev. Phytopathology* **45**: 263-88.

Robinson, A.F., Heald, C.M. Flanagan, S.I. Thames, W.H. and Amador, J. 1987. Geographical distribution of *Rotylenchulus reniformis*, *Meloidogyne incognita* and *Tylenchulus semipenetrans* in the lower Rio Grande Valley as relation to soil texture and land use. *Ann. App. Bio.* **1**: 20-25

Robinson, A.F., Cook, C.G., Bradford, J.M., Bridges, A.C. and Bautista, J. 2002. Difference in cotton yield, root-growth and *Rotylenchulus reniformis* following deep soil fumigation. In: Proc. *The Beltwide Conference* **3**: 564

Sakhuja, P.K., Jhooty, J.S. and Kang, M.S. 1986. Widespread incidence of root knot nematode, *Meloidogyne incognita* on cotton in Punjab (India). *Curr. Sci.* **55**: 740-41.

Sakhuja, P.K.; Chopra, B.L.; Sharma, J.R. and Singh, I. 1987. Evaluation of carbofuran and sebufos against root knot nematode, *Meloidogyne incognita* on American cotton (*Gossypium hirsutum* L.) *J Cotton. Res. Dev.* **1** : 213-15.

Sasser, J.N. 1979. Economic importance of *Melodogyne* in tropical countries. In: Root knot nematodes (*Meloidogyne* spp), systematic, biology and control, F. Lamberti and C.E. Taylor (eds.), Academic Press.

Sasser, J.N. and Freckman, D.W. 1987. A world perspective on nematology: In : Vistas on Nematology, (J.A. Veech and D.W. Dickson eds.) U.S.A. pp. 7-14.

Singh, B. and Jain, R.K. 1988. Comparative biology of root-knot nematode (*Meloidogyne incognita*) on cotton (*Gossypium hirsutum*) and tomato (*Lycopersicon esculentum*). *Ind. Jour. Nematology* **18**: 349-50.

Singh, J., Vats, R and Jain, R.K. 1998. Influence of different crop rotations on cotton yield under *Meloidogyne incognita* infested conditions. International Conf. on *"Food Security and Crop Science"*. Nov., 3-6,1998, Hisar, India, p. 232-33.

Sivakumar, C.V. 1992. Nematode pests of cotton. In : *Nematode Pests of Crops*, D.S. Bhatti and R.K. Walia (eds). CBS Publishers and Distributors, New Delhi, pp. 202-13.

Sivakumar, M. 2009. Efficacy of bio-control agents in management of reniform nematode, root-rot complex in cotton. *Ann. Plant Prot. Sci.***17**: 200-02

Smith, A.L. and Taylor, A.L. 1941. Nematode distribution in 1940 regional cotton wilt plots. *Phytopathology* **31**: 771.

Starr, J.L., Carneiro, R.G. and Ruano, O. 2005. Nematode parasites of cotton and other tropical fibre crops. In : Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, M. Luc, R.A. Sikora and J. Bridge (eds.), CAB International, Wallingford, UK, pp. 733-750.

Starr, J.L., Heald, C.M., Robinson, A.F., Smith, R.G. and Krausz, J.P. 1993. *Meloidogyne incognita* and *Rotylenchulus reniformis* and associated soil textures from some cotton production areas of Texas. Suppl. *Jour. Nematology* **25**: 895-99

Tanveer, M. and Haq, E.U. 1975. Prevalence of nematodes in cotton fields of Pakistan. *Pakistan Cotton* **20**: 45-54.

Tekchand, Jain, R.K. and Chauhan, M.S. 1992. Studies on histopathological changes due to *Meloidogyne incognita and Rhizoctonia solani* in cotton (*Gossypium hirsutum) J.Cotton Res. Dev.* **6**: 160-65.

Thirumalachar, M.T. 1946. Preliminary note on the eelworm of cotton plants. *Proceedings of the Indian Science Congress*, 273-78.

Timper, P., Kone, D., Yin, J.F., Ji, P.S. and Gardener, B.B.M. 2009. Evaluation of an antibiotic producing strain of *Pseudomonas fluorescens* for suppression of plant parasitic nematodes. *Jour. Nematology* **41** : 234-40.

Tu, C.C., Cheng, Y.S. and Kuo, F.L. 1972. An investigation of cotton nematicides of Taiwan and preliminary study on the effects of reniform nematode, root knot nematode and stubby root nematode on cotton. *Plant Protection Bulletin Taiwan* **14**: 95-109.

Varaprasad, K.S., Sud, U.C. and Swarup, G. 1986. Relationship between *Rolylenchulus reniformis* densities and host damage with reference to tolerance levels. *Ind. Jour. Nematology* **17**: 11-16.

Vats, R., Singh,J. and Jain, R.K. 1997. Efficacy of neem based pesticides against root-knot nematode (*Meloidogyne incognita*) infecting cotton (*Gossypium hirsutum*). National. Sym. IPM. Indian Constraints and Opportunities, Oct., 23-24, 1997, New Delhi. Abst. p. 34.

Vats, R., Singh, J. and Jain, R.K. 1998. Efficacy of a few chemicals as seed dip treatment against root knot nematode in cotton. Proc. III International. Symp. Afro-Asian Soc. of Nematologists, April, 16-19, 1998, Coimbatore India, p. 187-89.

Vats, R., Singh, J. and Jain, R.K. 1998. Effect of a few organic manures against root-knot nematode (*Meloidogyne incognita*) infecting cotton (*Gossypium hirsutum).* Proc. Natl. Symp. on *"Rational Approaches in Nematode Management for Sustainable Agriculture"* Nov., 23-25, 1998, GAU, Anand, India, 1998. pp. 10-12

Vats, R., Singh, J. and Jain, R.K. 1999. Prevalence of root-knot nematode (*Meloidogyne incognita*) and identification of its races in cotton growing areas of Haryana. *Ind. Jour. Nematology* **29**: 199-201.

Verma, K.K. 1997. Role of a few abiotic and biotic factors in root-knot (*Meloidogyne incognita*) disease incidence on cotton. (*Gossypium hirsutum*) in Haryana. *Ph.D. (Thesis)* CCS HAU, Hisar.

Verma, K.K. 2011. Management of root-knot nematode and root-rot fungus complex in cotton through bioagents. In Proc. Nat. Sym. on *"Nematodes: A Challenge under Changing Climate and Agricultural Practices"* held at Kovalam (Kerala) from 16-18th Nov., 2011. pp. 78

Verma, K.K. and Jain, R.K. 1999. Prevalence and distribution of phytoparasitic nematodes associated with cotton in Haryana. *Ind. Jour. Nematology* **29**: 192-93.

Verma, K.K. and Jain, R.K. 2001. Role of soil organic carbon on root knot disease of cotton and uptake of a few biochemical constituents. *Ind. Jour. Nematology* **31**: 38-43.

Verma, K.K. and Jain, R.K. 2004. Role of vesicular arbuscular mycorrhiza (VAM) in cotton, *Gossypium hirsutum*. National Symp. on *"Changing World Order Cotton Research, Development and Policy in Context"* at ANG Ranga Agri. Univ., Hyderabad, Aug., 10-12, 2004, p.132

Verma, K. K., Jain, R. K. and Dabur, K. R. 2011. Screening for resistance and management of root-knot nematode, *Meloidogyne incognita* on *Bt* cotton. In: *Proceedings "World Cotton Research Conference-5, Technologies for Prosperity"*, organized by International Cotton Advisory Committee, held at Mumbai, India from November 7-11, 2011, Abstract no. 86.

Verma, K.K. and Nandal, S.N. 2009. Managing potential of fungal antagonists against root-knot nematode as affected by inorganic fertilizers in cotton. In : Proc. Nat. Sym. on *"Bt Cotton: Opportunities and Prospects"* held at Central Institute for Cotton Research, Nagpur 17-19 November, 2009. pp. 101.

Wang, K.N; Riggs, R.D; Crippen, D. 2005. Isolation, selection and efficacy of *Pochonia chlamydosporia* for control of *Rolylenchulus reniformis* on cotton. *Phytopathology* **95** : 890-93.

Wyk, R.J.V., Prinsloo, G.C., Villers, D.A.D. and Meclure, M.A. 1987. A preliminary survey of plant-parasitic nematode genera in the cotton-producing areas of South-Africa *Phytophylactica* **19** : 259-60.

Yang, Y., Dehg, X.M. and Liu, G.Z. 1992. Studies on species and genera of plant parasitic nematodes in cotton fields in Sichaan. *Journal of South West Agricultural University* **14**: 292-95.

CROP IMPROVEMENT, BIOTECHNOLOGY AND POST HARVEST TECHNOLOGY

19

Cotton in Gujarat - A review

B. G. SOLANKI
Main Cotton Research Station, Navsari Agricultural University, Surat - 395 007
E-mail : cottonist@nau.in

Cotton has been the king of apparel fibre. It has played a vital role in the history of mankind and civilization. Due to its importance in agricultural as well as industrial economy, it is also called as “white gold”.

Inspite the incoming of synthetic fibres, cotton still holds an outstanding position. It is a chief cash crop in several parts of the country and plays a vital role in national economy. Gujarat is one of the main cotton producing states in India. It covers about 25 lakh hectares area under cotton, producing 100 lakh bales of lint, about 34 lakh tonnes of cotton seed and 60-65 lakh tonnes of stalks aggregately valued at about 16000-18000 crores of rupees. On the national basis, the state contributes about 39 per cent of the total cotton produced in the country from 26 per cent of the area under cotton. The average yield of lint/ha in the state was 609 kg against 485 kg of the country in the year 2008-2009.

History and development of the crop : The exact period when cotton fibre was used first is not known. Archaeological excavations of about 300 BC in Indus river valley and *Riguweda* hymns written about 15 centuries BC revealed use of cotton fibre. Marco Polo mentioned the cultivation of tree cotton in Gujarat in about 1290 AD. Cotton has been grown in this country since time immemorial and history, recorded and unrecorded, bears witness to the claim that this fibre is indigenous to this country, particularly the Asiatic types *G. arboreum* and *G. herbaceum*. However, attempts to put cotton growing on a scientific basis and introduce the New World species, *G. hirsutum* into this country date back to the middle of the eighteenth century. The area, now forming the State of Gujarat, figured prominently in these early attempts at the introduction of American Cotton, but repeated trials at Surat and Bharuch, however, failed to yield encouraging results. Nevertheless, efforts at selection of improved strains from the existing mixture were pursued with vigour in the state and in course of time, Fletcher made a real breakthrough with the isolation of the famous strain, 1027 ALF from a cross between Kumpta and Goghari, suitable for cultivation in the Surti tract. In 1919-20 an area of about 6000 acres in Gujarat tract was sown with the selection 1A and this could fetch a premium of ‘ 22 to 75 per candy over the Surat cotton. The establishment of the Indian Central Cotton Committee in 1921 gave the much needed impetus to cotton work in the state. As a result of the work carried out here for the control of bollworm, an effective plant puller was designed and employed for uprooting cotton plants at the end of the season to minimize over wintering of the pest. The first textile mill in Gujarat was set up in Bharuch in 1843, providing further fillip to cotton cultivation in the state.

The soils, suitable for cotton cultivation in Gujarat vary from the sandy soils of Kutch and the alluvial soils of Ahmedabad and Kheda districts to the black cotton soils of Central and Southern Saurashtra regions. The rainfall is moderate (50 to 125 cm) and the maximum temperature during the growth period may lie between 38° to 41°C.

Gujarat has long been known for the fine *G. herbaceum* cotton, it had been growing from the days of yore. The famous muslins of ancient India, probably, owed their origin to these types of cottons. The cottons known as Oomras to the trade included *G. arboreum* cottons or bengalense or indicum origin grown in the Mathio tract of Gujarat, possessing coarse loamy soils, called "gorat". These are grown in June-July and harvested in the months of October to December. The earlier cotton of this region, known as Mathio (due to resemblance of its leaves to those of math, (*Phaseolus aconitifolius*) was, in fact, the Khandesh Jadi Mixture. This along with the *G. herbaceum* cotton Wagad used to be called Dholleras by the trade, after the name of the port in Kathiawar through which it was shipped. A scheme for the improvement of the Mathio cotton was initiated at Amreli in 1937. Trials were laid out with early strains of Wagad (*G. herbaceum*) and some improved *G. arboreum* strains like N. Roseum, Jarilla, Benilla, Verum and Cawnpore 520. Of these, Cawnpore 520 was found suitable and distributed for cultivation in 1942. Further, selection work in the local material led to the release of variety, Pratap in 1945. This possessed a better ginning outcome, fibre length and spinning capacity, than the local cotton under cultivation. Simultaneously, work on crosses of Cawnpore 520 with Jarilla and Pratap as well as those of Pratap with the Madras, *G. arboreum* Karunganni was in progress and this eventually resulted in the isolation of CJ 73 from the cross, Crawnpore 520 x Jarilla and this, which proved superior to Pratap, was released for general cultivation in the region in 1958-59 under the popular name, Sanjay.

The early *G. herbaceum* cottons grown in the state were Wagad, Bharuch and Surat. These were grown under rainfed conditions in the black soils, alluvial soil or red laterites. The sowing was done in June to August and the crop harvested in the months of January to March. Lalio cotton of North Gujarat and South Kathiawar used to suffer from frost attack often due to late maturity. A solution to this problem resulted from the introduction of the early maturing (hence frost escaping) Mathio (*G. arboreum*) cotton in South Kathiawar, and the closed boll type Wagad and some improved Bharuch types in North Gujarat. Similarly, Goghari, a high ginning poor quality G. herbaceum cotton of Middle Gujarat was also replaced by name improved Broach type.

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The earliest cotton of South Gujarat was Surti local (also called Surti- Bhroach). Work on the improvement of G. herbaceum cottons was being pursued at the Government Agricultural Research Station at Surat, established long back in 1896. I A Long Boll, released in 1919 which succeeded Surti Local, was a selection from the same, possessing four per cent higher ginning percentage. This in time, yielded place to 1027 ALF evolved at Kirkee Farm from a cross between Goghari and Kumpta made in 1901. This cotton which was released in 1923 displayed a higher length and fineness, but suffered from a lower ginning percentage. This was corrected by backcrossing 1027 ALF with the higher ginning per cent, 1A Long Boll, and a new variety Suyog resulted. This variety, released in 1945, however, was found to be late maturing and susceptible to wilt attack as well as drought conditions. Then followed Vijalpa, in 1951, combining a higher yield, earliness, and wilt resistance, and Sujay (3943), a dwarf, high yielding variety from the cross (RF. Dwarf x 2334) in 1971.

Cotton improvement work started in earnest at Bharuch (Middle Gujarat) with the establishment of a Research Centre there in 1926. The variety BD 8 was given out in 1936. As a result of intensive work on hybridization with Comilla (*G. arboreum* race cernuum) and Wagale (*G. arboreum* race burmanicum) and Goghari selections, a variety named Vijay was evolved in 1943 from the cross, (BD 8 x Goghari A 2). Back crossed to BD 8. This variety, possessing wilt resistance, higher ginning percentage and better fibre quality found favour in the whole of Middle Gujarat and parts of South and North Gujarat. This was followed by the most popular variety, Digvijay released in 1956. Digvijay was evolved from the cross (Vijay x 1027 ALF) x Vijay. Then came G.Cot.11, a high yielding, early maturing variety evolved from the cross (3200 x EP 2) has been released in 1979. subsequently a high yielding early maturing variety G.Cot.17 evolved from the cross (1762 x Yerli 197-2) was released in 1995 for middle Gujarat cotton zone. This was totally replaced by G.Cot.23 released in 2000. This variety a cross of 625 BB x GBhv 41 became very popular not only in Middle Gujarat but in Wagad zone as well. Most recently a variety G.Cot.25 has been released in 2010 for whole Gujarat.

Another important cotton of Gujarat was Wagad, named after an area in Kutch in which probably it was grown first. This cotton, bearing indehiscent bolls, owes its origin to the perennial, closed-boll types of Baluchistan. As a result of selection in the local material carried out at the Cotton Research Station, Viramgam (established in 1922), the cotton Wagad 8 was isolated in 1933. This recorded an increase of 11 per cent in yield and 4 per cent in ginning percentage over the local, but had poor lint quality. Hybridization of Wagad 8 with 1027ALF and segregate 22-3-1-3 from Surat gave rise to the varieties Wagotar (in 1943) and Kalyan (in 1947). Crosses of Wagad with closed-boll types from Iran and USSR proved useless. Of the two mentioned above, Kalyan proved superior and more acceptable and this spread to the western part of the Wagad tract and Western part of North Gujarat. This was released for general cultivation in 1947. Further march in the direction improvement led to the evolution of V 797 from the cross (Kalyan x Vijay) x Kalyan. This was released for general cultivation in 1966 and found a congenial home in the medium black soils of Amadavad, Mehsana and Banaskantha as well as in Junagadh, Kutch and Surendranagar districts. This is extensively grown even today in Wagad region. To satisfy the demand of this area for open boll type, due to increased labour rates for shelling, a new variety G.Cot.13, evolved from the cross (Kalyan x 1802) had been released in 1981, followed by G.Cot.21 in 1998 which made increase in wide area in the state. Most recently a semi open variety Anand *desi* cotton 1 has been accepted for release due to bigger bolls and earliness.

Due to the textile revolution in Great

Britain, the then East India Company attempted to introduce American cotton for cultivation in India during the 18th century. This cotton was grown on experimental basis on cultivators' fields in Gujarat from 1797 to 1873 with no success. Hence, the major efforts were made to improve the indigenous cottons, particularly after the establishment of research station at Surat in 1896. However, the systematic research work on cotton was started in 1904 at the station for the first time in country. In addition to the improvement of indigenous cotton the attempts were made to combine the fibre quality of American cotton. *G.* hirsutum with the general adaptability of Asiatic cottons, *G. herbaceum* and *G. arboreum,* as the American cottons failed to adapt in Gujarat conditions. Systematic interspecific hybridization work was started in 1925 involving *G. arboreum, G. herbaceum* and *G. hirsutum* which was intensified in 1938 under the scheme for interspecific hybridization in cotton. The two economically successful varieties that resulted were 170-Co.2 (Deviraj) and 134-Co-2-M (Devitej). These were the commercial varieties, developed at Surat from crosses, involving Asiatic and American cottons and were released for cultivation in 1951-1952. Further work in this direction led to the evolution and release of the extra long staple strain Gujarat 67 in 1963. This replaced Devitej entirely and Deviraj partly. However, Deviraj continued to enjoy popularity with the cotton growers, because of its greater adaptability and resistance to moisture stress.

The entire research work has been strengthened from time to time particularly from 3rd FYP when work on various disciplines, particularly agronomy and plant protection besides breeding work was strengthened. Inception of All India Coordinated Cotton Improvement Project gave it a further boost.

In 1974, the new short branched, sympodial type, IAN 579(188) was released as G.Cot.100. However, these rapidly yielded place to the famous, hybrid Hybrid 4, blazing a new trail in cotton cultivation, that became the rage of the country. The cross (Co.2 x Tomentosum) repeatedly back-crossed to G. hirsutum, made and stabilized at Surat gave highly hairy "Cotom" types. One of such "Cotom" types was crossed with Indore 2 at Indore and the stabilized material from this gave CTI types. CTI types yielded the selection, KW 66-2096 at Indore/ Khandwa and from this the variety G.Cot.10 was isolated at Surat. This amazing variety released for general cultivation in 1974 has found a congenial home, not only in several other states in the country, but also neighbouring Burma. "Cotom" type has also given rise to the locally adopted variety "Khapatia" which has obtained recognization as G. Cot.12 (1981). This was followed by G.Cot.14 (1986) and G.Cot.18 for Saurashtra region. In the mean time a drought tolerant variety G.Cot.16(1995) was released for rainfed tract of Middle Gujarat. Most recently a high yielding variety G.Cot.20 (2008) has been released from Surat for irrigated areas of whole state.

Cotton research station, Surat has been a trail blazer for its reach achievement. Though intra and inter- specific hybrid variety development work has both in progress in the State since the advent of the second quarter of the century, real success came only in 1967-68, when Gujarat shot into world fame with the launching of the World's first commercial hybrid from Surat. Hybrid 4 (1971) is an intra hirsutum cross between the extra long staple variety, Gujarat-67 and American Nectariless, an exotic variety from U.S.A. This is truly remarkable cotton combining an extraordinary productivity with excellent quality. Its range of adaptability, too, is outstanding, leading to its finding favour with farmers, over more than half the country. This hybrid was landmark in the history of cotton and proved to be harbinger for other researchers in the country and abroad. This fired the imagination of the breeders elsewhere and several cotton hybrid followed in its wake.

An even more remarkable hybrid was the high yielding, early maturing G.Cot.Hy 6 released in 1980 which found favours from the growers beyond the borders of Gujarat from spinners across the country. An entirely new approach in cotton cultivation was introduced with the release of perennial budded cotton variety G.Cot.101 in 1977 for adivasi farmers in backward areas. A short duration early maturing hybrid G.Cot.Hy 8 suitable for double cropping and rainfed cultivation was released in 1988. Concurrent efforts illuminated in the release of first ever desi hybrid G.Cot.DH 7 in 1984 which had high yield potential, tolerance to pests and diseases coupled with earliness. This was another feather in the cap of this station. In fact it proved to be trend setter for desi hybrids in the country. In 1989, the first ever extra long staple desi cotton hybrid G.Cot.DH 9 was released. The pace of introduction of newer technologies and hybrid has constantly been on move. A short duration early maturing hybrid G.Cot.Hy 8 suitable for double cropping and rainfed cultivation was released in 1988 and was popular amongst farmers from Punjab to Pondicheri. Than a new intra hirsutum hybrid G.Cot.Hy 10 with high yield potential giving continuous flush was released in 1995. This was followed by a new versatile hybrid G.Cot.Hy 12 in 2005 suitable for both rainfed and irrigated condition. Efforts for developing ELS hybrid finally culminated with the release of G.Cot.102 in 2002. Simultaneously, the first GMS based intra arboreum hybrid G.Cot.MDH 11 was also released in 2002. Recently a new intra hirsutum hybrid G.Cot.Hy 10 with high yield potential giving continuous flash has been given to farmers for cultivation in 1995. The pace of introduction of newer technologies high yielding varieties and hybrids has constantly been on move. Some of the finest material with desired quality traits and tolerance to biotic and abiotic stress is in pipeline to see the light of the day. The result and impact is appealing. The average productivity in the state has touched 368 kg/ha despite only about 27% cotton area being irrigated in the state.

Since introduction of *Bt* cotton in India in 2002, upto 2012 there was a dominancy of private sector and in the *Bt* seed industry. But,, Navsari Agricultural University break the ice and introduced first public sector *Bt* hybrid *i.e.* G.Cot.Hy 6 (BG II) and G.Cot.Hy 8 (BG II) which was followed by G.Cot.Hy 10 (BG II) and G.Cot.Hy 12 (BG II) in 2015.

Future challenges : Due to introduction of Bt cotton and favourable season and crop condition since last ten years, Gujarat occupied the highest position in cotton production and productivity at National level. Due to *Bt era*, in some area the socio-economic level of cotton growers was boosted up. But, at the same time the threatening issues are emerging in cotton cultivation. Mealybug havoc after 3-4 years of *Bt* introduction in Gujarat was noticed and was tackled very well. Thereafter, pink boll worm(PBW) issue became headache for cotton researchers as well as growers. The state and central government compelled to address the issue. Besides this, illegal *Bt*, avoidance of refugee crop, abnormalities in cotton morphology are the major issues in cotton cultivation and in coming years there may possibilities of new unknown issues in cotton cultivation.

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Resurgence of *desi* cotton – A status of past, present and future

A.MANIVANNAN

Central Institute for Cotton Research, Regional Station, Coimbatore 641 003

E-mail : mani.vannan.461@gmail.com

ABSTRACT : Cotton is a commercial crop used for its fibre in textile industries. Cotton belongs to the family Malvaceae, the genus name is *Gossypium*. Species of cotton broadly classified into old world cotton (diploid 2n=2x=26) and new world cotton (tetraploid2n=4x=52). Old world cotton consists of two distinct species namely *Gossypium arboreum* (*karunganni/ nadan* cotton) and *Gossypium herbaceum*(*uppam* cotton),these two species of diploid cotton broadly known as *desi* cotton (native species) or Asiatic cotton. After the American civil war, British government introduced the *Gossypium hirsutum* to India and other colonized countries to cater the need of textile industries of England. At the time of independence, *desi* cotton occupied 98 per cent area (2.79 mha of *arboreum* and 1.39mha of *herbaceum*) and American cotton shared only 2 per cent (0.14mha). During 2000 the area of *arboreum* reduced to 1.46mha and *herbaceum* to 0.95mha due to increase in area under hybrids (3.64mha) and *hirsutum* (2.48mha) cotton. Since the introduction of Bt cotton area under *desi* cotton has been reduced to less than 1 per cent. *Desi* cotton known for its ability to grow in marginal environment especially *herbaceum* prefers to grow in coastal region. *Desi* cotton possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids. *Desi* cotton almost exhibits immune to the vector borne leaf curl virus. Due to short, coarse and weak fiber traits make them unsuitable for modern machine textile industries. However during 17-18th century, *desi* cotton was being spun by handcrafters, the cloth was so fine *e.g.* Dhaka muslin (Dhaka *malmal*). Machine and electrospinning needs high strength fibre, this property lacks in *desi* cotton. In spite of poor fibre traits, these short stable cotton used for denim, upholstery and surgical cloths. Recent past the trend is reversing, the demand for short stable cotton is 2% however the production is 1%; this makes a lot of hope for increasing the area of *desi* cotton. Concentrated varietal improvement resulted in the release of long linted variety like PA-255 (Parbhani), DLSA 17 (Dharwad), MDL2463 (A.P) and Jawahar Tapti of arboreum cotton with fine fibre qualities created a hope to satisfy the requirements of textile industry. Recent havoc of whitefly and leaf curl incidence in *hirsutum* demands a hardy genotype; by the virtue of above facts the true resurgence of *desi* cotton is not far away.

Key words : *arboreum*, *desi* cotton, *herbaceum*

Mankind attained full civilization after started wearing the cloth; in particular cotton revolutionized a complete civilization by means of giving different products from lint to yarn. Since then Cotton has been known as cash crop mainly for its fibre values in textile industries. Cotton belongs to the family Malvaceae, the genus name is *Gossypium*. Species of cotton broadly classified into old world cotton (diploid 2n=2x=26) and new world cotton (tetraploid2n=4x=52). Old world cotton consists of two distinct species namely *Gossypium arboreum* (*karunganni/ nadan* cotton) and *Gossypium herbaceum*(*uppam* cotton),these two species of diploid cotton by and large known as *desi* cotton (native genotype) or Asiatic cotton.

Origin : Both *arboreum* and *herbaceum* species are the lineage of A genome, possible speciation occurred between these species leads to formation of A_1 genome (herbaceous) and A_2 (*arboreum*) species. Two hypothesis exists for speciation of *arboreum*;(i) domestication occurred separately between these two species in parallel and diverged as distinct species before human interference(Fryxell,1979)(ii) there is no ancestor for *arboreum*, it was believed that 5000 years back, *arboreum* was evolved from the existing *herbaceum*(Hutchinson,1959). Cytologically the specie *arboreum* differs from *herbaceum* by a reciprocal translocation (Gerstel and Sarvella,1956).

Genome size : All diploid species are believed to be originated from a common ancestor and divereged as eight different (A to K) species. However, *G. arboreum* (A_2) and *G. raimondii* (D_5) are the putative donor species for the A and D chromosome groups, respectively. *G. arboreum* (1,746 Mb/1C) has a genome size that is twice that of *G. raimondii* (Li *et al.,* 2014). Molecular analyses revealed that divergence of *G. arboreum* and *G. raimondii* from their common ancestor is approximately 2 - 13 million years ago, (Wikstrom *et al.,* 2001).

Races of *arboreum* : *Gossypium arboreum* grouped into five races namely *indicum, bengalense, cernum, burmanicum, sinense and soudanense*. Indus valley believed to be the site of origin though there is no clear cut ancestor of *arboreum* exists. *G. arboreum* species well spread across the Indian Subcontinent. Race *indicum* found in peninsular region of India (Andhra Pradesh and Tamil Nadu), high quality cotton crop as an annual and wild form also found in this region. Genetically race *indicum* is more closely related to *herbaceum* than other races of *arboreum*(Sillow,1944). Race *indicum* has been called as *Karunganni* in Tamil Nadu; *Gaorani* in Maharashtra, Karnataka and Andhra Pradesh, *Mathio* in Gujarat. Remnants taken from Mohenjo Daro (3000-2700 BC), lint traits resembled to *arboreum*(Gulati and Turner,1928). Race *indicum* further moved towards east (north eastern states) and formed as perennial with long dropping linted bolls called as race *burmanicum*(Dacca). At the same time race *indicum* moved towards African side through Arabian plains diverged as separate race *soudanense*(*senaar* tree cotton). Race *burmanicum* moved through yellow river basin of China became annual in nature emerged as distinct race *sinense*. Race *burmanicum* which developed frost tolerance capacity set aside as distinct annual race *bengalense*(*Oomura* or *Bengaldeshi* cotton), which become commercial crop of North India. *Comilla* is vernacular name of the race *cernum* found at Assam hills and Bangladesh (Hutchinsion,1954 & Sillow,1944).

Races of *herbaceum* : *Gossypium herbaceum* grouped into four races namely *africanum, acerifolium, persicum, kuljianum,* and *wightianum*. Unlike *arboreum*, *herbaceum* race *africanum* is putative ancestor for all the modern races. Southern part of the African continent is believed to be the home for the race *africanum*. *G. herbaceum* race *africanum* was found in the form of xerophytic(open vegetative type) in African continent, this race is much similar to the species *arboreum* race *indicum* found in Western India (Braak, 1947).The most primitive type of the cultivable form of *herbaceum* is perennial similar to race *acerifolium* found from Mekran in Baluchistan, through Arabia and across the Sahara to West Africa(Ansari,1941& Hutchinson,1949). *Herbaceum* race had undergone climatic stress across different geographic regions and adopted into various racial forms such as *persicum, Kuljianum, wightianum*. Through traders, race *africanum* moved via Indian Ocean route and reached to the Arabia, where the domestication of *herbaceum* occurred. From Arabia, perennial raced called *acerifolium* moved towards North Africa. Perennial race *africanum* further moved towards Iran region where they adopted to a prolonged cold winter and short summer duration resulting into annual race *persicum*(Levant cotton). *G.herabceum* moved further towards north region of India and underwent habituation of hot, short summer and long winter climate emerged as new race *kuljianum*. Crop domestication of *G. herbaceum* annual race at Western India distinctly formed as new race *wightianum*(*Waghad, Kalyana, Jayadhar*)(Hutchinsion,1954 & 1959).

Ecological and geographical distribution of *desi* cotton in India : India having wider geographic region with different climatic zones, here both *arboreum* and *herbaceum* grows; whereas in particular area there is an introgression of two species also found. *G. arboreum* race *bengalense* found in North India and in some parts of the Pakistan, these races are short and very coarse fibre with long maturity. G. *arboreum* race *indicum* found in both North and South India, towards down south, it is called as *Karunganni* in Tamil Nadu suitable for very harsh environment; *Mungari* in Karnataka as it sown by early monsoon on set, *Mathio* in Gujarat. However, *Pundro* cotton in Andhra Pradesh possesses fine fibres. Mixed race of *indicum* and *bengalense* found in central India suited for rain-fed condition; *Gaoran*i is mainly grown over Maharashtra state. G. *arboreum* race *cernum* is a big boll type called as *Gharo* cotton in Assam and Bengladesh(Despande *et al.,*2004).

In case of *G. herbaceum*, race *wightianum* called as *uppam* cotton in Tamil Nadu, as it grows along the sea shore region of Bay of Bengal. In Karnataka, it was sown by late after onset of monsoon called as *Hingari*. *Dhummad* cotton in Junagadh and Kathiawar region of Gujarat, *dhummad* is a closed boll type as it requires high labour for ginning. *Wagad/Kalyan* type possesses open boll type which grown in Rajasthan and parts of Gujarat. *Jayadhar* is grown at rainfed tracts of Northern Karnataka (Kulkarni *et al.,*2009; Despande *et al.,*2004 & Narula *et al.,*2001).. Gujarat is the major state growing *G.herbaceum* cotton under three different situations: (i) In the Ghed area, where sea water intrudes and the water is brackish (ii)In the coastal desert sands with salinity and drought (iii)In the inland black cotton soil where salinity and drought are major problems. Form of *G. herbaceum* race *wightianum* found growing mixed with *G. arboreum* race *bengalense* in Western India(Dhummad x Mathio), and with *G. arboreum* race *indicum* in Southern peninsular India(*Mungari* x *Hingari*). Occasionally crossing between these two species occurred and fertile F_1 also been produced, however, there were a heavy breakdown noticed in F_2. It reinforces the species isolation between these two species (Silow, 1944).

Virtues of *desi* cotton

- Possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids.
- It is having resistance towards various diseases especially it shows immune to the vector borne leaf curl virus (CLCv)
- It is highly suitable to rainfed ecosystem being drought tolerant crop
- It is suitable for sustainable crop production
- It requires less cost of cultivation(low or no cost of crop protection)
- It is known for its ability to grow in

marginal environment especially *herbaceum* prefers to grow in coastal region

- Natural colour cotton such as Brown linted varieties *G.arboreum*, namely, Cocanada-1 and Cocanada-2 suitable for manufacturing of ecofriendly cloths

Infirmness of *desi* cotton

- Poor fibre quality (less strength and length) and coarse fibre properity of desi cotton unsuitable for modern day electrospinning
- Poor plant architecture (Smaller boll size and open boll type results in cotton shedding)
- Small flower hinders manual hybrid seed production unlike tetraploids
- More number of monopodia with lanky, tall plant type (*herbaceum*)
- Very longer duration of maturity (180-210 days in *herabceum*)
- *Herbaceum* genotypes are more susceptible to grey mildew than *arboreum*

(I) ***Arboreum* cotton Improvement**

Genetic potential of *arboreum* cotton (Deshpande *et al.,* 2004 & Kulkarni *et al.,* 2009)

Desi cotton by its inherent potential has the coarse fibre, less fibre length (<20mm) and poor spinnability (10s), with concentrated breeding efforts at different AICCIP centres namely Parbhani, Bharuch and Dharwad resulted in development of long linted *arboreum* with higher fibre length from 26 to 28mm, ginning out turn from 37 to 38 per cent, spinnability from 10s to 30s and yield increased from 300 kg/ha to 1400 kg/ha(Table.1).

Heterosis breeding : Crossing between *arboreum* lines with *herbaceum* genoytpes produced high yielding hybrids which outperformed over tetraploid hybrids in rain-fed eco system. Hybrids namely G.cot Dh 7, G.cot Dh 9, DDH 2 and PHA 46 were produced through interspecific hybridizing among diploid species. However, manual hybrid seed production was very tedious because of tiny flower nature. Genetic Male Sterility (GMS) had been exploited by using the sources GMS1, GMS 2 and GAK 423. Hybrids *viz.,* AAH1, AKDH7 and G. cot MDH 11 were produced employing GMS. These GMS based hybrids were not popular because of its short fibre and poor spinnability(Meshram and Wadodkar,1992). There is no CMS source available for exploiting heterosis(Khadi *et al.,*2004).

Ideotype breeding : Ideal plant type is called as ideotype, based on optimum plant architecture effort has to be oriented towards development of such a prototype plant is known as ideotype Breeding. In general, *arboreum* genotype possesses tall, lanky plant with weak stem; selection in such genotypes focuses on semi dwarf plant type with stiff, strong stem (Sing

Table 1. Important varieties of *arboreum*

Varieties	Yield	Fibre Length	Spinnability
G12,G22,G46 (Maharashtra);Maljari, Zarilla(Madhya Pradesh); K2,K5(Tamil Nadu)	300kg/ha	21-22mm	10-20s
PA 32, AKH 4, Y1 (Maharashtra),CJ 73 (Gujarat), K1(Tamil Nadu), Veena (Andhra Pradesh)	700kg/ha	23mm	20s
PA 255, PA 183(Parbhani Turab), AKA 8401(Maharashtra); MDL2463(Andhra Pradesh)	1400kg/ha	26-28mm	30s

and Narayanan, 1999).

Hirsutization of *arboreum*: Introgression of *hirstum* lines with *arboreum* background is called hirsutization of *arboreum*, resulting lines possess long lint. Parbhani and Dharward centers produced long linted *arboreum* lines *viz.,* PA402 and DLSa17 respectively (Despande *et al.,*2004; Kulkarni *et al.,*2002&2009).

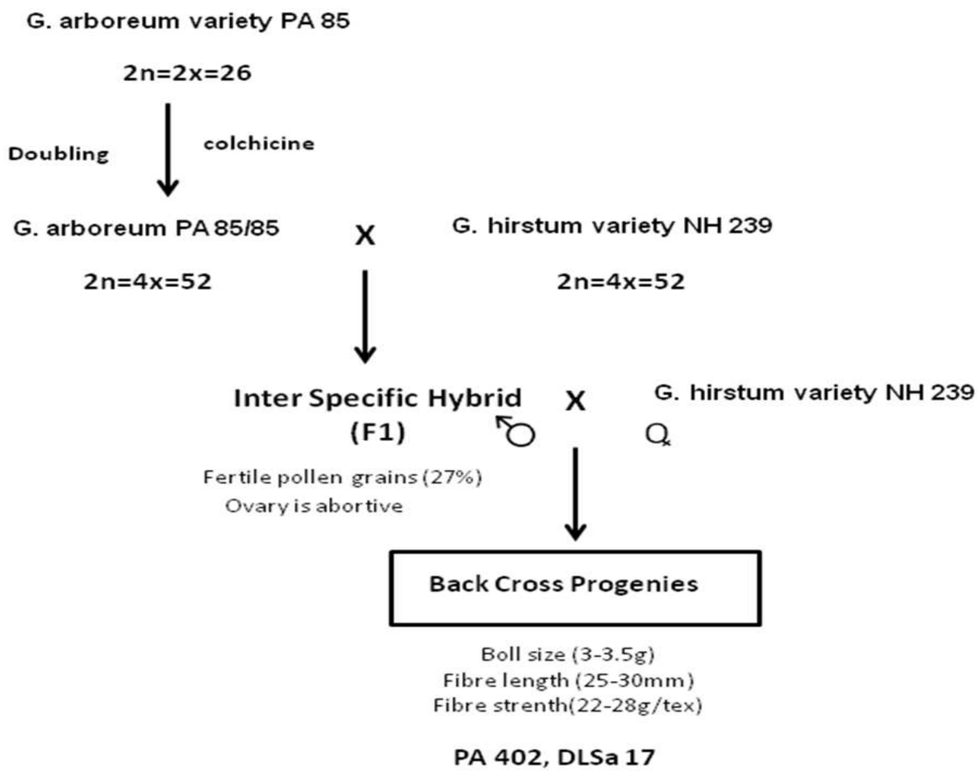

Fig 1. Hirsutization of arboreum cotton

(II) ***Herbaceum* cotton improvement**

Three distinct *G.herbaceum* territory have emerged for herbaceum growing namely *Wagad, Surti* (or) *Bharuchi* and *Kumpta* . *Surti/ Bharuchi* and *Kumpta* are fully open boll and named after parts of Surat and Bharuch of Gujarat. *Wagad* on the other hand is closed boll type, it has to be picked as such from plant and opened manually. Vagad is a place in Kutch region of Gujarat where it was first grown, hence the name *Wagad* derived. *G. herbaceum* Improvement started in 1896 at Surat and later it was strengthened at Dharwad (1904) in Karnataka; Bharuch (1913) and Viramgam (1922) in Gujarat.

Genetic potential (Narula *et al.,* 2001)

Three criteria are being considered as hall mark in *herbaceum* improvement viz., 1. High seed cotton yield, 2.high ginning out turn and 3. Early maturity. With this yard stick different breeding methods namely Selection, Pedigree method, Back Cross method, Mutation Breeding and Heterosis breeding were employed for the improvement of *herbaceum* cotton(Table.2). Concentrated efforts on *herbaceum* breeding yields into the development of many important varieties among which Digvijay (1956), V 797 (1965) and G. Cot 13 (1981) in Gujarat and Jayadhar (1950), Suyodhar (1963) and DB-3-12 (1983) in Karnataka (Table 3). Narula *et al.,*2001 had reviewed the *herbaceum* improvement in detail. Here below the brief account of their review.

G.herbaceum cotton genotype RAHS 14 was found to be saline tolerant, high yielding, early and well adapted at many locations. This genotype could be promoted in coastal areas of peninsular India for enhancing cotton productivity and income of farmers, especially under severe salinity stress conditions. The high yield potential of *G.herbaceum* varieties namely DB.3-12, G.Cot. 13 and G.Cot.21 could be demonstrated at several locations even under adverse situations in marginal soils. A promising strain of *G. herbaceum* – RAHS 131 has been identified under marginal conditions with a yielding ability of 500-800kg/ha in coastal areas. *G.herbaceum* genotypes namely RAHS 14, RAHS 119, RAHS 131 and hybrids G.Cot.DH.7 and G.Cot.DH.9 yielded around 600-900kg/ha in highly saline areas of Ankola, wherein sea water intrusion was seen and consequently, crops like green gram and black gram failed(Anonymous, 2003).

Ideotype breeding : In case of herbaceum genotype in nature of producing bushy and high number of monopodia(5-6) and late in maturity, ideotype focuses on open plant type, more number of sympodia with few monopodia(1-2).

(III) **Technology Mission on Cotton**

Under the umbrella of Technology Mission on Cotton (TMC), improvement of desi cotton genotypes has been undertaken in phased manner with different objectives.

Technology Mission on Cotton Mini Mission - I : Programmes in phase - I : TMC MM1.1 aimed at development of diploid cotton cultivars with high fibre quality. North Indian diploid cottons were improved (High yielding with low fibre quality) into long linted genotypes by means of shuttle breeding employing long linted diploids of south Indian genotypes introgressed into northern Indian lines with help of off season nursery. In this programme centres namely Parbhani, Hissar, Ludhiana, Sriganganagar, Dharwad and Coimbatore were involved (Anonymous, 2007).

Technology Mission on Cotton Mini Mission - I : Programmes in phase - II : TMC MM1.1 aimed at development and promotion of medium and long linted diploid cottons**.** The project is launched for development and promotion of desi cotton with high fibre qualities suitable for rain-fed cultivation to strengthen the economy of marginal cultivars. Centers namely

Table 2. Breeding strategies employed for *G. herbaceum* improvement (Narula *et al.,*2001)

Method	Varieties developed
Selection from local	1 ALB, Dharwad-1, Dharwad-2, Wagad-8, BD-8.
Pedigree method	Jayawant, Suyog, Jayadhar, Suyodhar, Raichur-51, G. Cot 11, G. Cot 13, G. Cot 17, G. Cot 21, G. Cot 23.
Back cross method	Wagoter, Kalyan, Vijalpa, Vijay, Digvijay, V 797
Mutation Breeding	DB-3-12
Heterosis Breeding	GDH-7, GDH-9, Pha 46, MDCH-201; DDH-2.

Table 3. List of *G. herbaceum* varieties released in India (Narula *et al.,* 2001)

S.	Variety (year of release)	Pedigree	Area of adaptation	Remarks
1.	Dharwad 1 (1918)	Selection from Kumpta local	Karnataka	Wilt susceptible
2.	1 ALB (1919)	Selection from Surat local	South Gujarat.	High yielding and high GOT but was discontinued in favor of 1027 ALF
3.	Dharwad 2	Selection from Kumpta local	Karnataka	Wilt tolerant
4.	1027 ALF (1923)	Goghari x Kumpta	South Gujarat.	Snow white quality cotton.
5.	Jayawant (1930)	Dharwad 1 x Dharwad 2	Karnataka	Susceptible to late rains.
6.	Wagad 8 (1933)	Selection from Wagad local	North Gujarat	Spinning value was lesser than local.
7.	BD 8 (1938)	Selection from Bharuch local	Central Gujarat	Wilt tolerant
8.	Wagotar (1942)	(Wagad-8 x 1027 ALF) x Wagad-8.	North Gujarat	High GOT but drought susceptible.
8.	Vijay (1943)	(BD-8 x GA-26) x BD-8	Central Gujarat	Had irregular spinning though had high GOT and abiotic tolerance.
9.	Suyog (1945)	1027 ALF x 1 ALB	South Gujarat	Late and susceptible to drought.
10.	Kalyan (1947)	(Wagad 8 x Surati-22-3-1-3) x Wagad 8.	North Gujarat	Immense flowering potential to tide over unfavorable weather.
11.	Jayadhar (1950)	KFT (12-2-5 x IA 14-3)	Karnataka	Wilt tolerant with an ability to withstand dry spells. Still covers around 0.1 m ha.
12.	Vijalpa (1952)	(Vijay x 1027 ALF) x Vijay	South Gujarat	-
13.	Digvijay (1956)	Vijay x (Vijay x 1027 ALF)	Central Gujarat	Still occupies around 0.1 m ha, preferred highly by the millers due to high spinnability.
14.	Suyodhar (1963)	(Jayadhar x Suyog) x KFT-12-2-5.	Dry belt of North Karnataka	Suited to low rainfall areas.
15.	V 797 (1966)	(Kalyan x Vijay) x Kalyan	North Gujarat	Closed boll, tolerant to wilt and fast winds.
16.	Raichur-51 (1968)	RK-19 x NS-12	North Karnataka.	Suitable for low rainfall.
17.	Sujay (1971)	Dwarf mutant x 2324	South Gujarat	Good combiner, parent of GDH-7
18.	G. Cot 11 (1979)	3200 x EP2	Central Gujarat	Early and high yielder than Digvijay but low boll weight.
19.	G. cot 13 (1981)	Kalyan x 1802	North Gujarat	First semi open boll variety for North Gujarat.
20.	Renuka(DB-3-12)(1983)	Mutant of Western 1	North Karnataka	Earliest among all the released varieties of herbaceum.
21.	G. Cot 17 (1995)	1762 x Yerly 197-3	Central Gujarat	Has high GOT, tolerant to wilt but smaller boll size.
22.	G. Cot 21 (1998)	1502E (G. Cot 13 x 4011D)	North Gujarat	Semi open boll variety that recorded 25% increase in yield after 1965 in Wagad area.
23.	G. Cot 23 (2000)	625BB x GbBhv-41	Central Gujarat	Big boll variety having good boll opening.

Bharuch, Banswara and Dharwad were concentrated on *herbaceum*. Centres *viz.,* Sirsa, Ludhiana, Hisar, Nagpur, Sriganganagar, Parbhani, Khandwa, Rahuri, Akola, Mudhoi and Kovilpatti were on *arboreum*(Anonymous, 2012).

Technology Mission on Cotton Mini Mission - I : Programmes in phase - III

TMC MM 1.4 launched with objective of evaluation of genotypes for surgical cotton. This project focuses on surgical cotton (absorbent cotton) production. Coarse textured lint with short fibre length of *arboreum* cotton can be easily arranged into layers for surgical purpose. Demand for surgical cotton is growing at the rate of 10% per annum across the world. Centres *viz.,* Nagpur, Coimbatore, Sirsa, Akola, Nanded, Dharwad, Faridkot, Jalgaon and Hissar are involved in this project (Anonymous, 2013).

Status of *desi* cotton : After the American civil war, British government introduced the *Gossypium hirsutum* to India and other colonized countries to cater the need of textile industries of England. At the time of independence, *desi* cotton occupied 98 per cent area (2.79 mha of *arboreum* and 1.39mha of *herbaceum*) and American cotton shared only 2 per cent (0.14mha) (Santhanam,1997). In 1960s, *arboreum* strains AK 235(Maharashtra and Madhya Pradesh) and the improved *Gaorani* in Southern Maharashtra and Northern Andra Pradesh were predominant in cultivation. While in *herbaceum* Jayadhar(Karnataka) and V797(Gujarat) were leading cultivars(Santhanam,2004). During 2000 the area of *arboreum* reduced to 1.46mha and *herbaceum* to 0.95mha due to increase in area under hybrids (3.64mha) and *hirsutum* (2.48mha) cotton. Since the introduction of Bt cotton; area under *desi* cotton has been reduced to less than 1 per cent (Table 4) (Kranti, 2015 & Narayanan *et al.,* 2014).

Table 4. Area and Production of Desi cotton in India

Years	*G. arboreum*		*G.herbaceum*	
	Area (m ha)	Production (m ton)	Area (m ha)	Production (m ton)
1947-1948	2.79	0.253	1.39	0.109
1989-1990	1.28	0.217	0.98	0.130
2013-2014	1.17	0.129	0.58	0.064

Desi cotton known for its ability to grow in marginal environment especially *herbaceum* prefers to grow in coastal region. Coastal agricultural system in the States of Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu are suitable for growing *G.herbaceum* cotton. Thus, *G.herbaceum* cotton can be introduced in problem soils in coastal agricultural eco-system for its rejuvenation and prosperity. *Desi* cotton possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids. *Desi* cotton almost exhibits immune to the vector borne leaf curl virus. Due to short, coarse and weak fiber traits make them unsuitable for modern machine textile industries. However during 17-18th century, *desi* cotton was being spun by handcrafters, the cloth was so fine *e.g.* Dhaka muslin (Dhaka *malmal*). Machine and electrospinning needs high strength fibre, this property lacks in *desi* cotton. In spite of poor fibre traits, these short stable cotton used for denim, upholstery and surgical cloths. Recent past the trend is reversing, the demand for short stable cotton is 2% however the production is 1%; this makes a lot of hope for increasing the area of *desi* cotton.

Future strategies

- *Desi* cotton possesses resistance to

sucking pests' offers ecofriendly crop due to less or no spray of pesticides.

- Diploid cotton exhibits tolerance towards abiotic stress like drought, their capacity to grow in rainfed condition offers unique solution to climate change.
- *G.herbaceum* has special adoptability to grow in marginal environment in particular towards costal saline area; paves the way for answer to problem soils.
- Both *arboreum* and *herbaceum* are having the potential for organic cotton production in the rainfed ecosystems. This organic cotton fetches higher revenue from export point of view.
- Recent incidence of whitefly menace in Northern India reveals that desi cottons are better tolerant towards such a pest.
- *Desi* cotton exhibits almost immune reaction to leaf curl disease in contrast teteraploid cottons are highly susceptible to CLCV.
- Breeding programme to improve the fibre quality of *desi* cotton is necessary to crab the textile value of its fibre.
- Breeding for ideal plant type in both *herbaceum* and *arboreum* is needed to tap the potential for input responsible crop production in irrigated condition.
- Screening for resistance to Grey mildew and Alternaria blight is needed to identify the genetic stocks for disease tolerance.
- Brown linted varieties *G.arboreum*, namely, Cocanada-1, Cocanada-2 could be exploited for natural colour yarn. This natural coloured cotton gives solution to dye effluent menace.
- Breeding to produce glandless seed with glanded plant part for low gossypol cotton seed oil.
- Modern biotechnological tools such as molecular marker and genetic transformation techniques could be employed for improving fibre quality traits of *desi* cotton.

REFERENCES

Anonymous. 2003. Prospects of *herbaceum* cotton cultivation for improving agricultural output of coastal agro ecosystmes. In: N.Gopalakrishnan, K.N.Gururajan, S.E.S.A.Khader, U.G.Patel, S.S.Patil, T.S.Raveendran, S.Thirumeni and J.S.V.Sambamurthy(Eds), T.P.Rajendran, CICR,RS, Coimbatore.

Anonymous.2007. TMC Programmes in Phase – I, TMC Mini Mission 1.1. Annual Report, CICR, Nagpur.

Anonymous.2012. TMC Programmes in Phase – II, TMC Mini Mission 1.1. Annual Report, CICR, Nagpur.

Anonymous.2013. TMC Programmes in Phase – III, TMC Mini Mission 1.4. Annual Report, CICR, Nagpur.

Ansari, M. A. A. 1941. Survey of cottons of Baluchistan. *Indian. J. Agric. Sci.,* **11:** 59.

Braak, C. 1945. On the Climate of and Meteorological Research in the Netherlands Indies. In Science and Scientists in the Netherlands Indies. Board for the Netherlands Indies, Surinam and Curacao.

Deshpande, L.A., K.S. Baig, V.N. Kulkarni, Matishchandra and S.S. Kakde. 2004. Strategies to improve cultivated diploids – Perspective. In: B. M. Khadi, I.S. Katageri, S.S. Patil, H.M. Vamadevaiah, B.R. Patil and S.M. Manjula (Eds), Proceedings of International symposium on "Strategies for Sustainable Cotton Production- A Global

Vision"1, Crop Improvement, 23–25 November 2004, University of Agricultural Sciences, Dharwad, Karnataka (India), pp. 25–30.

Fryxell, P.A. 1979. Natural History of the Cotton Tribe, College Station, Texas A&M University Press.

Gerstel, D. U and P.A. Sarvella 1956. Additional Observations on Chromosomal Translocations in Cotton Hybrids, *Evolution,* **10 :** 408-14.

Gulati, A.N and A.J. Turner. 1929. A note on early history of cotton. *Journal of the Textile Institute, Transactions,* **20:** 1-9.

Hutchinson, J.B. 1954. New evidence on the origin of the old world cotton. *Heridity,* **8:** 225–41.

Hutchinson, J.B. 1959. The application of genetics of cotton improvement. Cambridge University Press, Cambridge.

Khadi,B.M., V.N.Kulkarni, M.S.Bisankoppa and H.M.Vamadevaiah. 2004. Introgression derivatives from *Gossypium arboreum* (A2) and *G.hirsutum* (AD1) serve as source to identify 'D' genome genes – A study. Book of Abstracts of International Cotton Genome Initiative 2004, Hyderabad, India. 10–13 October, 2004, pp. 85.

Kranti, K.R.2015. Desi Cotton - Returns?. *Cotton Statistics & News.,* **15 :** 1-4.

Kulkarni, V.N. 2002. Hirsutisation of *G. arboreum* cotton and genetic emendation of *G. hirsutum* for sucking pest resistance. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, India.

Kulkarni,V.N., B.M. Khadi, M.S.Maralappanavar, L.A.Deshapande and S. S. Narayanan. 2009. The Worldwide Gene Pools of *Gossypium arboreum* L. and *G. herbaceum* L. and their Improvement; In: Genetics and Genomics of Cotton, Plant Genetics and Genomics: Crops and Models 3, A.H. Paterson (ed.), Springer Science &Business Media, LLC.pp69-97.

Meshram, L.D. and M.B.Wadodkar.1992. Male sterility in Asian cotton *Gossypium arboreum.*L., *Hybrid cotton newsletter.,* **2 :** 3.

Narayanan,S.S., Parchuri Vidyasagar and K. Srinivasu Babu.2014. Cotton Germplasm in India — New Trends; In: World Cotton Germplasm Resources Edited by Ibrokhim Abdurakhmonov.pp.87-118.

Narula, A.M., Acharya, S., Khadi, B.M. and Kulkarni, V.N. 2001. *Gossypium herbaceum* cotton in India. Directorate of Cotton Development, Department of Agriculture and Cooperation, Mumbai, India.

Santhanam, V. 1997. Agri-history of Cotton in India-An Overview; In: Asian Agri-History, **1 :** 235-51.

Santhanam, V. 2004. Emerging trends in conventional breeding for cotton improvement, In: B. M. Khadi, I.S. Katageri, S.S. Patil, H.M. Vamadevaiah, B.R. Patil and S.M. Manjula (Eds), Proceedings of International symposium on *"Strategies for Sustainable Cotton Production- A Global Vision"1*, Crop Improvement, 23–25 November 2004, University of Agricultural Sciences, Dharwad, Karnataka (India), pp. 1-4.

Sillow, R.A. 1944. The genetics of species development in the Old World cottons. *Journal of Genetics*, **46 :** 62-77.

Singh, P. and S.S.Narayanan. 1999. Cotton Improvement Procedures, In: Hand Book of Cotton in India, Sundaram V. , Basu A K., Krishna Iyer K R., Narayanan S S., Rajendran T P (Eds): Indian Society for Cotton Improvement, Mumbai, pp.41- 56.

21

American cotton genotype Phule Yamuna (RHC 0717) : Potential for central zone of India.

R. W. BHARUD, A. R. AHER AND D. R. NAGAWADE

Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722

E-mail : cotton_mpkv@rediffmail.com

ABSTRACT : The overall mean performance indicated that genotype Phule Yamuna RHC 0717 (1911 kg/ha) recorded 33.96 per cent and 19.96 per cent higher seed cotton yield than the zonal check LRA 5166 (1427 kg/ ha) and local check (1593 kg/ha), respectively. The RHC 0717 was adjudged as the best entry in the twenty one trials out of thirty trials conducted at different locations in respect to yield and yield attributing characters. Likewise, this variety performed excellent fibre properties *viz.* Ginning percentage (34.5), long fibre length (27.85 mm), average fibre strength (23.23 g/tex), average micronaire (4.5), excellent uniformity ratio (51) and very good maturity (>81); which were suitable for medium stable cotton. The variety showed disease free reaction to grey mildew, resistant to BLB, moderately resistant to ALB and tolerant to sucking peats and bollworm. Therefore, this genotype is recommended under the name 'Phule Yamuna' for commercial cultivation in irrigated tract of central zone of India comprising Maharashtra, Madhya Pradesh and Gujarat state.

Key word: Cotton, *G. hirsutum,* variety

Cotton is the world's leading natural fibre crop and it is a cornerstone for textile industries worldwide. It is a large diverse and economically variable genus, which includes many diploid and tetraploid species indigenous to most of the tropical regions of the world (Fryxell *et al.*, 1992). The cultivated tetraploid species *G. hirsutum*, also referred to as 'upland cotton' accounts for about 95 per cent of the global cotton production. Consequently, a great majority of worldwide cotton breeding programme have been focusing on improving upland cotton. With the increasing global demand for textile products, intense competition from synthetic fibre and textile industry's modernization, the need for higher yielding upland cotton cultivars with improved fibre quality has never been more critical (Vindhiyavarman, 2015).

India continued to maintain the largest area under cotton and second largest producer of cotton next to China with 35.29 per cent and 24 per cent of world cotton area and production, respectively. India also sustained the position of being the second largest consumer and exporter of cotton (Anonymous, 2015).

Looking to the inconsistent performance of *Bt* cotton hybrids since last few years under changing scenario of climate, groups of farmer's particularly cultivating cotton on marginal soils under rainfed / irrigated condition are looking forward for non *Bt* varieties / hybrids of American cotton. In India, presently more than 90 per cent area has been occupied by *Bt* cotton. In rest of the area, non *Bt* cotton variety / hybrids of *G. hirsutum / G. barbadence / G. arboreum / G. herbaceum* are struggling for survival. At this juncture, flow of releasing non *Bt* varieties / hybrids is need of the day, otherwise in coming years; these non *Bt* varieties may be diminished completely. Likewise, in the present scenario of *Bt* cotton, release of non *Bt* cotton varieties are extremely essential for using as a parent in crossing programme by the breeders for creating genetic variability.

MATERIALS AND METHODS

Requirement of the state is to have high yielding, stable genotype having tolerance to biotic and abiotic stresses with desirable fibre qualities. *G. hirsutum* basically possess good fibre properties used to be commercially rated lower than *barbadence* cotton. Development of such a high yielding stable genotype with desirable fibre qualities will help to improve cotton productivity and income of farmers in Maharashtra, Gujarat

Table 1. Detailed DUS description of Phule Yamuna (RHC 0717) with checks

SN	Characteristics as per National Test Guidelines (DUS)	Phule Yamuna (RHC 0717)	LRA-5166	Phule-688
1.	Hypocotyl : Pigmentation	Present	Present	Present
2.	Leaf : Colour	Green	Green	Green
3.	Leaf : Hairiness	Medium	Medium	Medium
4.	Leaf : Appearance	Flat	Flat	Flat
5.	Leaf : gossypol glands	Present	Present	Present
6.	Leaf : Nectaries	Present	Present	Present
7.	Leaf : Petiole Pigmentation	Present	Present	Present
8.	Leaf : Shape	Normal	Normal	Normal
9.	Plant : Stem Hairiness	Medium	Strong	Medium
10.	Plant : Stem Pigmentation	Present	Present	Present
11.	Plant : Height	Medium (110-120)	Medium (104.80)	Tall (110-120)
12.	Plant : Growth Habit	Semi-spreading	Semi-spreading	Semi-spreading
13.	Bract : Type	Normal	Normal	Normal
14.	Flower: Time of 50 % Flowering	**Medium (55-60)**	Late (67)	Medium (55-60)
15.	Flower : Petal colour	**Yellow**	Cream	Cream
16.	Flower : Petal Spot	Absent	Absent	Absent
17.	Flower : Position of Stigma	Exerted	Exerted	Exerted
18.	Flower : Filament Colour	Absent	Absent	Absent
19.	Flower : Pollen colour	**Cream**	Yellow	Yellow
20.	Flower: Male sterility	Absent	Absent	Absent
21.	Boll : Bearing habit	Solitary	Solitary	
22.	Boll : Colour	Green	Green	Green
23.	Boll : Shape Longitudinal Section	Ovate	Ovate	**Elliptic**
24.	Boll : Surface	Smooth	Smooth	Smooth
25.	Boll : Prominence of Tip	Pointed	Pointed	Blunted
26.	Boll : Opening	Open	Open	Open
27.	Boll : Weight	3.5-4.0	3.0 – 3.5	4.1-4.5
28.	Seed: Fuzz	Medium	Medium	Medium
29.	Seed : Fuzz Colour	Grey	Grey	Grey
30.	Seed Index	Medium (8.35)	Small (6.87)	Medium (9.74)
31.	Ginning %	Medium (34)	Low (27.67)	Medium (37)
32.	Fibre : Colour	White	White	White
33.	Fibre : Length (SL)	Med. long (26-27)	Medium (26.4)	Medium (26-27)
34.	Fibre : Strength S (3.2m)	Medium (22-23)	Medium 22.2	Medium (22-23)
35.	Fibre : Fineness (MIC)(Micronaire Value)	**Medium (4.8)**	Fine (3.9)	Fine (3.2)
36.	Fibre : Uniformity Ratio (UR)	Good (51)	Good (48)	Good (50)
37.	Fibre: Maturity (%)	84	84	83

Table 2. Performance of Phule Yamuna (RHC-0717) in comparison with checks over seasons for 15 locations in station, Multi Location and Coordinated Varietal Trials.

Yield and quality characters	Culture/ checks	Station trial (2008-2009)	MLT 2009-2010	MLT 2010-2011	MLT 2011-2012	MLT 2012-2013	MLT 2013-2014	Br-02a IET (2010-2011)	Br-03a PVT (2011-2012)	Br-04a CVT (2012-2013)	Mean	Increase over (%)
Seed cotton yield (kg/ha)	**RHC 0717**	2107	2251	1996	2399	1484	1418	1345	1930	2268	**1910.89**	-
	LRA 5166	1578	1272	1316	-	-	-	1057	1287	2049	1426.50	**33.96**
	Phule 0688	1674 #	1748	1433	2253	1212	1298	1330	1721	1748	1592.88	**19.96**
Lint yield (kg/ha)	**RHC 0717**	748	717	681	797	712	536	455	662	789	**677.44**	-
	LRA 5166	576	396	470	-	-	-	365	439	738	497.33	**36.22**
	Phule 0688	607 #	588	494	847	530	450	449	563	611	566.50	**19.58**
GOT (%)	**RHC 0717**	35.48	31.86	34.12	33.20	34.07	37.81	33.7	34.6	35.1	**34.44**	-
	LRA 5166	36.50	31.16	35.73	-	-	-	35.2	33.8	36.3	34.78	**-0.99**
	Phule 0688	36.28 #	33.62	34.50	37.61	33.23	34.70	34.3	32.0	34.9	34.36	**0.23**
Bolls /Plant	**RHC 0717**	33.0	43.0	39.0	46.0	49.0	42.7	27.2	24.0	35.7	**37.73**	-
	LRA 5166	31.0	36.0	31.0	-	-	-	23.9	18.0	34.8	29.12	**29.59**
	Phule 0688	28.6 #	37.0	34.0	43.0	44.0	43.0	28.8	23.0	31.2	35.50	**6.29**
Boll weight (g)	**RHC 0717**	3.19	3.5	4.2	3.40	4.47	4.07	2.9	4.1	3.6	**3.71**	-
	LRA 5166	3.28	3.4	5.7	-	-	-	3.2	4.0	3.5	3.85	**-3.44**
	Phule 0688	3.46 #	3.3	5.1	3.60	4.20	4.13	3.3	4.4	3.6	3.95	**-6.05**
2.5 per cent Span length (mm)	**RHC 0717**	28.1	27.9	27.9	26.9	28.9	29.5	26.8	27.3	27.3	**27.84**	-
	LRA 5166	30.2	29.1	29.7	-	-	-	30.5	29.7	24.8	29.00	**-3.98**
	Phule 0688	29.1 #	27.2	28.6	27.0	27.6	28.6	29.3	27.0	27.5	27.85	**-0.02**
Micronaire	**RHC 0717**	3.8	4.5	4.7	4.6	3.8	4.4	4.6	5.0	5.1	**4.50**	-
	LRA 5166	3.9	3.6	4.3	-	-	-	4.4	4.1	4.8	4.18	**7.57**
	Phule 0688	3.9 #	3.7	4.4	3.8	4.0	4.4	4.4	4.6	4.8	4.26	**5.57**
Bundle strength (g/tex)	**RHC 0717**	26.1	27.5	23.3	22.2	20.3	21.6	23.6	23.1	21.4	**23.23**	-
	LRA 5166	25.7	28.3	23.1	-	-	-	24.1	27.7	22.0	25.15	**-7.62**
	Phule 0688	22.3 #	25.4	22.1	23.1	19.8	22.8	22.5	21.8	22.5	22.50	**3.26**

Mean data of JLH 168

and Madhya Pradesh. So efforts were made at Cotton Improvement Project, MPKV, Rahuri during the year 2003-2008 and the strain RHC 0717 was developed by pedigree selection method.

The genotype was tested consecutively for six years under preliminary university trial, MLT and AICCIP trials. The university multilocation trials were conducted at Rahuri, Kopargaon and Padegaon during 2008-2009 to 2012-2013, whereas, the Co ordinated trials were conducted at five locations (Khandwa, Surat, Junagadh, Rahuri and Bhawanipatna) for three consecutive year *i.e.* 2010-2011 to 2012-2013. The fibre properties through HVI *viz.*, 2.5 per cent span length, uniformity, micronaire, strength, elongation as well as full spinning results were tested at CIRCOT, Mumbai. The genotype was tested for wider spacing as well as higher doses of fertilizers. It was also tested for major pests and diseases at MPKV, Rahuri as well as in Co ordinated trials. The statistical analysis was carried out according to Panse and Sukhatme (1985).

Table 3. Full scale spinning report of *G. hirsutum* variety Phule Yamuna (RHC 0717) at CIRCOT, Mumbai.

Sl No	Entry	SL	UR	Mic	Str	E(%)	Count1	CSP1	Count2	CSP2
1	RHC 0717	26.3	50	4.2	21.6	>7.0	30	2247	40	1988

RESULTS AND DISCUSSION

For development of genotypes selection pressure was applied on segregating population of Krishiratna hybrid (K 03/01-26-46) during 2003-2004 to 2007-2008, superior plant were selected up to F6 generation and then tested under different trials. The details description of existing strain along with checks is presented in different tables.

RHC 0717 is a medium tall, semi spreading genotype with yellow colour petals and cream colour anthers, which is distinct from both the checks (in LRA 5166 & Phule 688, the petals are cream and anthers are yellow in colour). The ovate bolls are smaller in size with pointed tip distinguish the genotype (Table 1).

The performance of existing genotypes for different quantitative characters in different trial is presented in Table 2. During 2008-2009 to 2023-2014, the strain RHC 0717 recorded a mean seed cotton yield of 1910.89 kg/ha as compared to 1426.50 kg/ha in LRA 5166 and 1592.88 kg/ha in Phule 688, which is 33.96 per

Table 4. Screening of Phule Yamuna (RHC-0717) against major diseases in Coordinated Varietal Trials.

Year of testing	Trial location	Proposed variety RHC 0717	Zonal (Ck 1) check LRA 5166	Local check (Ck 2)
A. Bacterial blight				
2010-2011	Bhawanipatna	1	2	2
	Guntur	-	3	3
	Surat	0	4	3
2011-2012	Surat	4	3	3
	Junagadh	2	2	2
	Rahuri	-	-	-
2012-2013	Surat	1	3	4
	Junagadh	1	2	2
	Rahuri	-	-	-
B. Alternaria leaf spot				
2010-2011	Bhawanipatna	1	-	-
	Guntur	-	4	3
2011-2012	Junagadh	4	3	4
	Rahuri	2	1	1
	Surat	4	3	3
2012-2013	Surat	-	-	-
	Junagadh	2	3	3
	Rahuri	2	1	2
C. Grey mildew				
2010-2011	Bhawanipatna	2	2	2
	Guntur	-	0	3
2011-2012	Junagadh	0	0	0
2012-2013	Surat	-	-	-
	Junagadh	-	-	-
	Rahuri	0	0	0

Table 5. Screening of Phule Yamuna (RHC 0717) against sucking pest complex and bollworm.

Year of testing	Trial location	Proposed variety RHC 0717	Zonal (Ck 1) check LRA 5166	Local check (Ck 2)
A. Jassids				
2010-	Bhawanipatna	2.12 (II)	3.45 (II)	1.82 (II)
2011	Rahuri	4.6 (III)	4.1 (III)	4.7 (III)
	Surat	5.8 (II)	7.4(III)	5.3 (II)
2011-	Junagadh	9.0 (II)	16.0 (IV)	6.8 (II)
2012	Rahuri	8.56 (II)	5.68 (II)	4.46 (III)
	Surat	3.90 (II)	2.80(II)	2.50 (II)
2012-	Surat	II	I	I
2013	Rahuri	I	II	III
B. Whitefly				
2010-	Bhawanipatna	1.05	1.05	1.09
2011	Rahuri	5.9	4.6	3.6
	Surat	6.2	5.5	5.4
2011-	Junagadh	28.0	17.0	27.9
2012	Rahuri	9.17	15.28	13.61
	Surat	2.60	0.20	2.70
2012-	Surat	3.42	3.85	4.25
2013	Rahuri	4.47	3.50	4.33
C. Thrips				
2012-	Surat	6.65	6.45	4.41
2013	Rahuri	4.25	4.59	4.53
D. Aphids				
2012-2013	Junagadh	6.38	7.20	6.33
E. Open boll damage (Boll basis)				
2010-	Rahuri	18.8	19.8	20.5
2011	Surat	35.5	54.2	57.9
2011-	Junagadh	8.83	8.97	12.12
2012	Rahuri	20.95	18.35	24.65
	Surat	12.83	23.41	48.70
2012-2013	Junagadh	18.02	22.93	14.20
F. Open boll damage (Locule basis)				
2010-	Rahuri	12.2	19.8	13.1
2011	Surat	25.7	54.2	52.1
2011-	Junagadh	3.43	3.62	4.10
2012	Rahuri	10.37	13.16	12.01
	Surat	7.66	18.71	30.67
2012-2013	Junagadh	11.20	14.65	9.16
G. Leafhopper				
2012-	Surat	1.48	1.46	1.8
2013	Rahuri	4.56	2.17	5.28
	Junagadh	2.93	3.08	2.88
H. Mealybug				
2012-2013	Surat	1.52	1.64	1.52

cent and 19.96 per cent increase over check varieties respectively. Likewise lint yield of RHC 0717 was 677.44 kg/ha as compared to 497.33 kg/ha in LRA 5166 and 566.50 kg/ha in Phule 688. The bolls/plant of existing genotypes was 38 as compared to 29 and 36 in LRA 5166 and Phule 688 respectively. For all other characters *viz.*, ginning outturn, boll weight, 2.5 per cent span length, Micronaire and bundle strength the genotype RHC 0717 recorded more or less equal mean values. The fibre quality traits tested for RHC 0717 culture under full spinning test by ICC mode revealed that, the span length of 26.3 mm and strength 21.6 g/tex. which can spun in between 30-40 counts (Table 4). The culture RHC 0717 was evaluated under field conditions at different locations of Central zone during 2010-2011 to 2012-2013 for disease and pest reaction. The test variety showed disease free reaction to gray mildew, resistant to Bacterial Leaf Blight and moderately resistant to Alternaria Leaf Blight (Table 5). Likewise the, the genotype was also found tolerant to sucking peats and bollworm (Table 6).

In view of superior fibre properties and yield potential over the *G. hirsutum* check varieties LRA 5166 and Phule 688, the strain RHC 0717 was released under the name “Phule Yamuna” and recommended for commercial cultivation in cultivation in irrigated tract of central zone of India in the year 2014.

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REFERENCES

Anonymous 2015. AICRP on Cotton *"Annual Report"* 2014-2015.

Fryxell, P.A., Craven, L.A and Stewart, J.M.C.D. 1992. A revision of *Gossypium* sect. Grandi Calyx (*Malvaceae*), including the description of six new species. *Syst. Bot.,* ***17:*** 91-114.

Panse, V. G. and Sukhatme, P. V. 1985. Statistical Methods for Agricultural Workers. ICAR, New Delhi, Fourth Ed.

Vindhiyavarman, P., Gunasekaran, M., Thangaraj, K. and AmalaBalu, P. 2015. TCH 1716 - An Extra Long Staple *G.hirsutum* Cotton Genotype. *Electronic Jour. Plant Breed.* **6 :** 838-41.

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Evaluation of *Bt* cotton hybrids for yield and fibre quality traits

K.V. SIVA REDDY, Y. SATISH AND V.CHENGA REDDY

Acharya N. G. Ranga Agricultural University, Regional Agricultural Research Station, Guntur - 522 034

E-mail : kvsivareddy@yahoo.co.in

ABSTRACT : A field experiment was conducted to evaluate fifty six intra-*hirsutum Bt* cotton hybrids including three *Bt* checks at Regional Agricultural Research Station, Lam farm, Guntur, Andhra Pradesh in *kharif* 2013-2014 following randomized block design with three replications. In the present investigation, analysis of data indicated significant differences between the *Bt* cotton hybrids for seed cotton yield which ranged between (2474 to 4116 kg/ha). Highest seed cotton yield (4116 kg /ha) was recorded with *Bt* hybrid KSCH 232 BGII followed by Ankur 2595 BG II (3981 kg /ha) and SP7517 BG II (3966 kg /ha). All these hybrids were significantly superior to *Bt* checks Bunny BG II (3234 kg /ha), Mallika BG II (3047 kg/ha) and Jaadoo BG II (2980 kg/ha). Number of bolls ranged from 29 to 58, boll weight ranged from medium boll (4.4 g) to big boll (6.5 g), 2.5 per cent span length from medium (27.2 mm) to long (33.6 mm) and bundle strength (20.8 g/tex) to strong (24.5 g/tex). Highest boll/plant was recorded by ACH 1 BGII followed by First class BG II. Higher boll weight was observed in Ankur 2595 BGII and ACHH 2 BGII hybrids. Whereas, Ankur 5464 BG II recorded highest 2.5 per cent span length and Ankur 2595 BGII and JKCH 8905 BG II shown maximum bundle strength. It is evident that some of the *Bt* cotton hybrids studied, have shown good performance in terms of both yield and fibre quality traits in the given environment.

Key words : *Bt* cotton, fibre quality traits, yield

Cotton is one of the important crops in India and it plays significant role in socio-economic status of Indian farmers. In India it occupies an area of about 12.655 million hectares and production of 40.0 million bales of cotton with an average productivity of 537 kg lint/ha (AICRP, Annual Report, 2014-2015). It plays a prominent role in farming and industrial economy of the country. With the introduction of *Bt* cotton hybrids, there has been a significant change in the cotton cultivation scenario of India. Now, around 90 per cent area under cotton is occupied by *Bt* cotton hybrids. However, the average production is very low compared to world's average. This is mainly because 70 per cent of cotton area is under rainfed condition. There are many number of *Bt* cotton hybrids were released by private companies which are under cultivation in farmers fields. But still there is a need to evaluate high yielding *Bt* cotton hybrids along with good fibre properties for specific locations. Hence, the present study was undertaken to identify the high yielding *Bt* cotton hybrid for this location.

MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2013-2014 at Regional Agricultural Research Station, Lam farm, Guntur, Andhra Pradesh. The present study was carried out with 53 *Bt* cotton hybrids along with three checks (Bunny, Mallika and Jaadoo) in randomized block design with three replications. The inter and intra-row spacing adapted was 105 x 60cm. Each plot consisted of four rows of 6 m length and

Table 1. Mean Seed cotton yield and fibre quality traits of different *Bt* cotton hybrids

S.No	*Bt* cotton hybrid	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	2.5 per cent span length (mm)	Bundle strength (g/tex)
1	Western Nirogi 108	3201	43	5.2	27.9	20.9
2	NCH 2108	3340	44	5.4	29.5	22.4
3	AC H 4	2996	34	6.3	32.1	22.8
4	SCH 505	3228	42	5.5	32.3	23.6
5	KSCH 207	3467	40	6.2	28.3	22.6
6	ACH 2	2599	29	6.2	31.0	23.6
7	KCH 3011	3595	38	6.4	30.9	23.9
8	SWCH 4823	3003	33	6.5	29.6	23
9	PCHH 4 (Saraswathi)	3000	35	6.4	32.4	23.5
10	ACH 1	3463	58	4.4	27.2	20.6
11	NBC 101	3946	46	6.1	29.9	23.5
12	SCH 311	3165	38	5.8	30.9	22.8
13	Ankur 2595	3981	43	6.5	31.4	24.5
14	Western Niogi 51	2923	41	5.2	27.2	21.5
15	ACHH 2	3040	36	6.5	29.9	23.7
16	JKCH 8905	3247	34	6.5	31.2	24.5
17	KCH 3021	3737	49	5.6	33.3	24.4
18	KSCH 232	4116	51	5.3	28.3	22.4
19	DPC 5102 (Aravind)	3569	45	6.1	31.7	22.7
20	First class	2942	55	5.6	29.2	22.2
21	IAHH 4202	2963	46	4.6	31.2	22.9
22	DPC 9104 (Aravind)	3665	46	5.8	29.6	22.1
23	ACH 104 2	2877	36	6.0	31.8	22.3
24	KSCH 233	2956	41	5.6	32.0	22
25	81 SS 33	2725	36	5.7	29.4	22.4
26	PCHH 5073 (Meenakshi)	2910	34	6.4	28.3	22.2
27	60 SS 66	2853	40	5.6	32.7	22.4
28	Ankur 3818	3380	43	6.1	30.7	22.8
29	KCH 3041	3655	46	6.0	31.3	22.6
30	KSCH 209	3080	46	5.1	28.4	21.7
31	741 SS 66	3827	45	6.2	31.6	24.3
32	Ankur 5464	2802	36	6.1	33.6	23.3
33	SP 7585	3033	46	5.1	27.9	22.6
34	Ankur 2224	3501	51	5.2	32.2	22.1
35	KSCH 229	3742	47	5.8	31.0	21.7
36	SCH 234	3919	54	5.5	30.8	21.9
37	KCH 3031	2606	37	5.9	33.0	23.7
38	RCH 797	3913	47	6.2	31.4	23
39	IAHH 178	3553	51	5.2	30.9	21.6
40	KCH 3001	3463	42	6.4	32.2	22.9
41	Surpass Asha	3320	46	5.4	32.4	23.5
42	NCH 1311	3419	42	6.3	32.9	22.7
43	Ankur 4858	3188	47	5.2	27.4	22.1
44	DPC 7102 (Arind)	2474	38	5.2	30.2	22.2
45	63 88 33	3619	53	5.2	31.3	23.1
46	NCH 1049	3314	38	6.4	31.8	23.3
47	RCH 779	3400	43	6.1	31.7	23.1
48	NBC 102	3267	46	5.3	27.8	20.7
49	SP 7517	3966	49	5.8	32.0	22.6
50	DPC 9105 (Arind)	3503	53	4.9	29.4	22.8
51	KSCH 234	3115	38	6.3	29.5	22.2
52	SCH 777	3770	47	5.9	32.8	23.6
53	SCH 333	3545	45	5.6	32.7	24.3
54	Bunny	3234	42	5.7	32.9	24
55	Mallika	3047	40	5.6	31.0	23.3
56	Jaadoo	2980	40	5.4	32.2	23.2
	GM	3306	43	5.8	30.8	22.8
	CD (p=0.05)	731.0	7.2	0.27	1.15	1.3
	CV (%)	13.8	10.5	2.9	2.3	3.5

observations were recorded on ten randomly selected plants from each genotype/replication for characters *viz.,* bolls/plant, boll weight (g) and whereas, seed cotton yield (kg/ha), 2.5 per cent span length (mm) and bundle strength (g/tex) were recorded on plot basis. Recommended dose of fertilizers and need based plant protection measures were carried out for management of sucking pests to ensure a near perfect expression of the genotypes. *Kapas* was taken from the first picking and the lint was subjected to fibre quality testing at Central Institute for Research on Cotton Technology (CIRCOT) Regional Unit Lam, Guntur.

RESULTS AND DISCUSSION

In the present investigation, analysis of data indicated significant differences between the *Bt* cotton hybrids for seed cotton yield which ranged between (2474 to 4116 kg/ha). Highest seed cotton yield was recorded by KSCH 232 (4116 kg/ha). The hybrids *viz.,* KSCH 232 (4116 kg/ha), Ankur 2595 (3981 kg/ha) and SP7517 (3966 kg/ha) recorded significantly higher yield than the three check hybrids Bunny (3234 kg/ha), Mallika (3047 kg/ha) and Jaadoo (2980 kg/ha). Whereas, NBC 101 (3946 kg/ha), 741SS66 (3827 kg/ha) and RCH 797 (3913 kg/ha) recorded significantly higher yield than the two check hybrids Mallika (3047 kg/ha) and Jaadoo (2980 kg/ha). KCH 3021 (3737 kg/ha) and KSCH229 (3742 kg/ha) recorded significantly higher yield than check hybrid Jaadoo (2980 kg/ha). bolls/plant ranged between 29 (ACH 2) and 58 (ACH 1). Highest bolls/plant was recorded by ACH 1 (58) followed by First class (55), SCH 234 (54), 638833(53), DPC 9105 (53), KSCH 232 (51), Ankur 2224 (51) and IAHH 178 (51) against checks Bunny (42), Mallika (40) and Jadoo (40). Boll weight ranged from 4.4 g to 6.5 g. The entries *viz.,* Ankur 2595, ACHH 2, JKCH 8905 and SWCH 4823 recorded highest boll weight (6.5 g) followed by KCH 3011, PCHH 4, PCHH 5073, KCH 3001 and NCH 1049 recorded 6.4 g boll weight compared with the checks *viz.,* Bunny (5.7 g) , Mallika (5.6 g) and Jaadoo (5.4 g).

For 2.5 per cent span length the values ranged from 27.2 mm to 33.6 mm. The entries Ankur 5464 (33.6 mm) and KCH 3021 (33.3 mm) recorded highest 2.5 per cent span length over the checks Jadoo (32.2 mm) and Mallika (31.0 mm). Bundle strength ranged from 20.6 g/tex to 24.5 g/tex. The entries *viz.,* Ankur 2595 (24.5g/tex), JKCH 8905 (24.5 g/tex), KCH 3021 (24.4 g/tex), 741SS 66 (24.3 g/tex), SCH 333 (24.3) having superior strength over the three checks Bunny (24.0 g/tex), Mallika (23.3 g/tex) and Jaadoo (23.2 g/tex).

The desirable hybrids in respect of seed cotton yield are KSCH 232, Ankur 2595 and SP 7517 whereas, with respect to fibre properties Ankur 2595 and KCH 3021 were identified in the present investigation for this location. However it needs further confirmation on multi location basis. Similar research studies on *Bt* cotton hybrids were also reported by Deshmukh *et al.*, (2013), Bhongle *et al., (*2014) , Sangwan *et al.,* (2013), Patil *et al.,* (2013) and Patel *et al.*, (2013).

REFERENCES

AICRP Annual Report. 2014-2015. All India Coordinated Research Project on Cotton. Coimbatore, Tamilnadu, India.

Deshmukh, S.B., Rathod, T.H., Bhongle, S.A., Nemade, P.W. and Patil, B.R. 2013. Comparative study of BGI and BG II cotton hybrids under rainfed condition. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8. : 42

Bhongle, S.A., Patil, B.R., Deshmukh, S.B. and Rathod, T.H. 2013. Evaluation of popular *Bt* cotton hybrids for fibre quality under rainfed conditions. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8.: 47

Patel, D.H., Patel, V.I., Vadodaria, K.V. and Kumar,V. 2013. Evaluation of *Bt* cotton hybrids under rainfed condition. National Seminar on *“Technology for Development and Production of Rainfed Cotton"* October 24-25: 11

Patil,B.R, Bhongle,S.A, Deshmukh,S.B, Nemade, P.W and Ingole, O.V. 2013. Evaluation of *Bt* cotton bybrids under rainfed condition. National seminar on *“Technology for Development and Production of Rainfed Cotton’* October 24-25 : 9

Sangwan,R.S., Siwach,S.S., Sangwan, O., and Pundir, S.R. 2013. Evaluation of performance of *Bt* cotton hybrids under different moisture conditions. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8. 53.

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Stability for seed cotton yield and its components in cotton (*Gossypium hirsutum L.*)

Y. RAMA REDDY, A.S.R. SARMA AND S. JAFFAR BASHA

Acharya N G Ranga Agricultural University, Regional Agricultural Research Station, Nandyal – 518502

Email: ramareddy.yettapu@gmail.com

ABSTRACT : Eleven diverse *G.hirsutum* genotypes were evaluated during *kharif* 2010-2011,2011-2012 and 2012-2013 to study their stable performance over the periods for nine characters *viz.* Bolls/plant, Boll weight, ginning percentage, halo length, micronaire, fibre strength, seed index, lint index and seed cotton yield/plot of cotton *(G.hirsutum).* The performance of G x E interactions revealed variation was found significant for the characters, bolls/plant, halo length, seed index and seed cotton yield for the characters indicating the seasons wise quite diverse with regard to their effect on the performance of the genotypes for different traits studied. Among the genotypes NDLH 1928 performed stable over environments for the trait, seed cotton yield.

Cotton is the most important fibre and cash crop. It is fulfilling the domestic needs as well as earning foreign exchange for the country. The average production of cotton in India is lowest among cotton growing nations of the world. One of the major constraints in realizing higher productivity is that the crop is grown under diverse agro climatic condition and is highly sensitive to environmental fluctuation which causes instability in the production from year to year. So the present study was carried out to assess the stability of some promising cotton genotypes developed at Acharya N.G.Ranga Agricultural University, Regional Agricultural Research Station, Nandyal with checks.

MATERIALS AND METHODS

The present study was carried out with eleven genotypes of cotton (*Gossypium hirsutum. L*). These genotypes were grown in three seasons *i.e.,* 2010-2011, 2011-2012 and 2012-2013 in a randomized block design with three replications at R.A.R.S, Nandyal. Each entry consisted of 4 rows of 6 m length with inter and intra row spacing of 60 x 30 cm. The observations were recorded on five randomly selected competitive plants from each genotype in each replication for nine component characters *viz.,* bolls/plant, boll weight (g), ginning percentage (%), 2.5 per cent halo length(mm), fibre strength(g/tex), micronaire(10^{-6} g/inch), seed index, lint index and seed cotton yield per hectare. The yield, yield components and fibre quality characters were analyzed. The stability analysis was carried out as per Eberhart and Russell model (1966).

RESULTS AND DISCUSSION

The analysis of variance for stability with regard to seed cotton yield, yield components and fibre quality characters are presented in table 1. It shows that mean squares due to genotypes

Table 1. Analysis of variance (pooled) for yield and fibre component characters in cotton

Source of Variance	df	Seed cotton yield/ha	bolls/plant	Boll weight (g)	Mean squares			Fibre strength (g/tex)	Seed index	Lint index
					Ginning percentage (%)	2.5 per cent span length (mm)	Micronaire (10^{-6} g /inch)			
Varieties	10	169257.48**	38.19**	0.41	4.74	5.31**	0.22**	0.85*	2.58**	0.6310**
Env.+(var.* Env)	22	678721.46**	154.1**	0.27	4.46	1.29**	0.02	0.29	0.08*	0.03606
Env+(Lin)	1	14123383.84**	2566.98**	0.46	65.99**	20.02**	0.03	1.92*	1.11**	0.34501**
Var.*Env.(Lin)	10	43318.18	72.28**	0.24	0.72	0.58	0.01	0.19	0.05	0.01387
Pooled deviation	11	34118.76*	9.13**	0.28**	2.27	0.25	0.02	0.22	0.02	0.02815
Pooled error	60	11945.62	1.48	0.023	2.66	0.79	0.015	0.49	0.08	0.05740

** Significant at both 5 % and 1 % *Significant at 5%

Table 2. Estimates of stability parameters for yield and fibre traits of 11 varieties of G. *hirsutum*.

S. No	Varieties	Seed cotton yield /ha			bolls/plant			Boll weight (g)			Ginning percentage (%)			2.5 per cent span length (mm)		
		$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di
1	NDLH 1870	2319.0	0.922	15485.1	25.5556	1.178	-1.9872	3.2111	-0.965	-0.0264	36.1111	1.056	-0.2067	26.8889	1.793	-0.9642
2	NDLH 1906	2723.4	1.092	-2080.2	27.0000	1.563	29.9405	3.0444	-0.352	-0.0263	33.4445	0.889	-2.7068	28.0000	1.354	-0.7492
3	NDLH 1928	2761.0	1.033	28888.1	22.7778	1.077	3.5564	3.6556	-0.138	0.0291	32.7778	0.722	-2.4291	29.4444	1.310	-0.9043
4	NDLH 1939	2504.8	0.937	-11443.0	21.3333	0.724	-1.4444	4.1111	2.702	-0.0080	33.0000	0.833	-1.5401	30.0000	1.016	-0.8444
5	NDLH 1943	2542.1	1.035	11709.3	23.6667	1.201	-1.6695	3.6333	0.971	0.3103	32.7778	1.056	-1.5401	28.2222	-0.388	-0.9445
6	NDLH 1969	2366.9	0.709	-5808.4	22.0000	1.287	11.7580	4.0444	6.723	1.1919	33.8889	1.444	0.6267	31.6667	1.016	-0.8444
7	NDLH 1973	2021.3	1.116	69240.2	15.3333	-0.110	19.1801	4.0222	-0.919	0.0127	34.5556	0.444	0.6264	29.6667	1.016	-0.8444
8	NDLH 1975	2349.7	0.857	148304.1	17.5556	0.230	2.2078	4.1444	-1.875	0.1800	34.8889	0.611	-1.5402	30.6667	0.827	-0.6559
9	NDLH 1976	2602.7	0.839	-11968.0	26.0000	1.364	-1.6231	3.6667	1.920	0.3966	32.3333	1.333	-2.0400	30.2222	0.872	-0.9413
10	NDLH 1983	2071.6	1.412	-10602.2	20.3333	0.759	19.6324	3.4556	2.716	0.3534	34.1111	1.056	6.4599	29.8889	1.510	0.7370
11	NDLH 1755	2374.4	1.049	11541.8	24.0000	1.727	-1.3269	3.4556	0.216	0.3280	35.7778	1.556	-2.9288	29.3333	0.677	-0.9123
Mean		**2421.5**	-	-	**22.32**	-	-	**3.68**	-	-	**33.97**	-	-	**29.46**	-	-
SEm		130.6	-	-	2.14	-	-	0.37	-	-	1.07	-	-	0.35	-	-

$\bar{\chi}$= Mean values; βi = Regression coefficient; S^2Di=Deviation from regression coefficient

S. No	Varieties	Micronaire(10^{-6} g /inch)			Fibre strength (g/tex)			Seed index			Lint index		
		$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di
			âi	**S^2Di**		**âi**	**S^2Di**		**âi**	**S^2Di**		**âi**	**S^2Di**
1	NDLH - 1870	4.5778	2.360	-0.0174	22.0778	0.814	-0.3621	7.2889	0.825	-0.1007	3.8444	0.438	-0.0982
2	NDLH - 1906	5.3000	0.292	-0.0025	20.6556	-0.325	0.2331	7.7000	0.486	-0.1033	3.7333	0.121	-0.0634
3	NDLH - 1928	4.7889	2.401	-0.0090	22.2222	3.288	-0.4737	10.4333	0.856	-0.0957	5.0556	0.642	-0.0279
4	NDLH - 1939	4.5889	0.085	0.0028	21.7444	0.033	0.1181	9.2222	0.781	-0.0758	4.2556	0.689	-0.0693
5	NDLH - 1943	4.4778	4.593	0.0024	21.1111	0.717	-0.3449	8.3556	1.901	-0.0370	3.5111	1.256	-0.1038
6	NDLH - 1969	4.9556	0.251	0.0205	21.5000	1.856	0.0466	9.9000	2.375	-0.1022	4.5556	2.164	-0.0590
7	NDLH -1973	4.6556	1.202	0.0238	21.5333	1.270	-0.4200	8.6778	0.517	-0.0990	4.3444	0.766	-0.0861
8	NDLH - 1975	4.7222	-1.858	-0.0078	20.933	1.953	-0.4317	9.5778	1.506	-0.1032	4.2111	-0.432	-0.0736
9	NDLH - 1976	4.7111	-1.693	-0.0019	21.6667	0.684	-0.4598	9.2778	1.180	-0.0659	3.9111	1.043	-0.0818
10	NDLH - 1983	4.6667	2.608	0.0122	22.1111	0.814	-0.4865	9.1333	0.028	-0.617	4.3000	1.217	-0.1038
11	NDLH - 1755	4.2222	0.788	-0.0053	22.2000	-0.097	-0.3264	9.3222	0.543	-0.0884	4.7778	1.095	-0.0675
Mean		**4.69**	-	-	**21.61**	-	-	**8.99**	-	-	**4.23**	-	-
SEm		0.09	-	-	0.33	-	-	0.11	-	-	0.12	-	-

were found significant for most of the characters except for boll weight. The environment + (G x E) was significant for most of characters indicating distinct nature of environment and G x E interactions in phenotypic expressions. The environment (linear) was significant for all the characters except for boll weight indicating difference between environments and their influence on genotypes for expression of these traits. The G x E (linear) interaction showed significance for number of bolls/plant. This indicated significant difference among the genotypes for linear response to environments and behaviour of the genotypes which could be predicted over environments more precisely and G x E interactions was outcome of linear function of environmental components. Hence, performance of genotypes could be predicted based on stability parameters which would be feasible and reliable.

Among 11 varieties tested, NDLH 1928 registered highest seed cotton yield/ ha (2761 kg/ha) and produced a regression value of 1.033(~1) which significantly deviated from one. The S^2d was found nonsignificant. These values indicated that, NDLH 1928 is stable for all environments (Nidagundi *et al.,* 2010, Patil *et al.,* 2007 and Fatihi Kill and Eyup Hareem, 2006).

The varieties NDLH 1928 for number of bolls/plant, NDLH 1973 for boll weight, NDLH 1983 variety for ginning percentage, NDLH 1973 variety for micronaire (10^{-6} gm/inch) under regression showed nonsignificant deviation from zero. Hence, these varieties are considered as stable performers.

As the deviation from regression for remaining characters were non significant but had negative values for almost all varieties. But, on the basis of regression values the performance of varieties over environment can be ascertained. Average performance of varieties NDLH 1969 and NDLH 1973 for 2.5% span length (mm) and the variety NDLH 1755 for lint index had âi value near to one indicating that they are suitable for all environments.

It can be concluded from the present study that NDLH 1928 was stable in its performance for seed cotton yield.

REFERENCES

Eberhart, S.A and Russell, W.A. 1966. Stability parameters for comparing genotypes. *Crop Science*. **6** : 36 – 40.

Fatih Kill and Eyup Harem, 2006. Genotype x environment interaction and stability analysis of cotton yield in Aegeon region of Turkey. *Journal of environmental biology*. **27** : 427-30.

Patil, B.C., Kumar.V., Ratnakumari, S., Mishra, O.S., Patil, S.S., and Khadi, B.M., 2007. Stability of *G.hirsutum* genotypes for performance across Indian rainfed ecosystem.

Nidagundi, J. M., Patil, S.S., Salimath, P. M. and Hegde, M.G. 2010. Stability studies in cotton (*Gossypium hirsutum L.*): can stable performance of cotton genotypes in the national trials be used as reliability index in determining stable hybrids. Crop Improvement. **37** : 201.

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Genetics of seed cotton yield and its attributing characters in cotton (*Gossypium hirsutum* L.)

S. RAJAMANI, G.M.V. PRASADA RAO AND S. RATNA KUMARI

Acharya N.G. Ranga Agricultural University, Regional Agricultural Research Station, Guntur - 522 034

E-mail : mani_breeder@rediffmail.com

ABSTRACT : Genetic material comprised of sixty, three way crosses derived from fifteen diallel crosses produced by crossing six diverse parents *viz.*, 241-4-2, G Cot 100, RFS 3438,65- 2(s)-3,Hyps 152 and Suvin were studied to obtain information on genetics of seed cotton yield and its attributing characters. Gene actions were analyzed by adopting biometrical technique, triallel analysis to get information on epistatic gene action in addition to additive and dominance variances.. The data was analyzed to assess inheritance of gene action for seed cotton yield and its attributing characters *viz.*, monopodia/plant, sympodia/plant, bolls/plant, boll weight, seed index, lint index and ginning outturn. All the traits studied were governed by additive x dominance component of epistatic gene action except lint index which is governed by dominance x dominance gene action. Breeding methods like heterosis breeding would be followed for development of commercial hybrids to obtain higher yields as most of the traits were governed by epistatic gene action. In addition to heterosis breeding special mating designs like bi-parental mating and inter mating in early generations would be adopted to isolate superior segregants from future generations. The order of parents in which crosses must be effected should clearly revealed by the study to obtain superior transgressive segregants.

Key words : Cotton, gene action, seed cotton yield

Cotton is the prime fibre crop of India and ranks first in terms of cultivated area and second in terms of production next to China. The main objective of any crop improvement programme is aiming at increasing yield and production of crop. However yield is a complex character which is poly genetically controlled and influenced by number of yield attributing characters. Information on gene action or genes that govern a particular character in a crop plant is essential for planning and execution of breeding programme successfully. Though different biometrical techniques are used to estimate gene action, triallel analysis is a potential tool to study information on additive, dominance and epistatic gene actions and variances. Triallel analysis also gives the information on order of parents in three way cross combinations for obtaining superior transgressive segregates (Ponnuswamy *et al.*, 1974).

Three way cross was denoted by (A x B) C has been defind as cross between, line “C” and single cross (A x B). Lines “A” and “B” are called as grand parents and line “C” as immediate parent or full parental line (Rawling and Cockerham 1962). In the present study an attempt has been made to obtain information on gene actions in controlling yield and its attributes.

MATERIALS AND METHODS

Field experiments were conducted at Regional Agricultural Research Station, Lam

Guntur of Acharya N G Ranga Agricultural University. The material comprised of 60, three way crosses derived from fifteen diallel crosses produced by crossing six diverse parents *viz.*, 241-4-2(1), G Cot 100 (2), RFS 3438 (3), 65-2(s)-3 (4), Hyps 152 (5) and Suvin (6) in triallel mating design. During *kharif* 2009 six parents were mated in half diallel fashion and fifteen single cross hybrids were produced. During 2010-2011 these 15 single crosses were mated with six orizinal parents in triallel fashion and 60 three way crosses were obtained. All the three way crosses along with single crosses and parents were evaluated in randomized block design in three replications with 105 x 60 cm^2 spacing containing single row with ten hills. Five plants were randomly selected from each plot for data collection on yield and attributing characters *viz.,* monopodia/plant, sympodia/plant, bolls/plant, boll weight(g), seed cotton yield(kg/ha), seed index, lint index and ginning outturn and the mean data was subjected to triallel analysis (Singh and Chaudhary, 1985) to draw valid conclusions.

RESULTS AND DISCUSSION

The analysis of variance revealed that the general line effect of first kind (*hi*) was significant for all the characters except the monopodia/plant and bolls/plant (Table 1). The general line effect of second kind (*gi*) was significant for all the characters and two line specific effects of first kind (*dij*) was also significant except sympodia and bolls/plant. The two lines specific effects of second kind (*sij*) was significant for bolls/plant, seed cotton/plant, seed index, lint index and ginning outturn. The three line specific effect was significant for bolls /plant, seed index, lint index and ginning outturn. The three way cross analysis provides additional information regarding epistatic components of variances and effects and the order in which the parents are to be involved in crosses. The estimation of various effects are would provide information on *gca* and *sca* effects of a line to utilize as grand parent or/as parent.

Monopodia/plant : The general line effect of first kind was positive and significant for parent Suvin (*hi* = 0.267) and it would be used as grandparent in production of significant three way crosses. Though Suvin, a good combiner as grandparent, the other parents *viz.,* Hyps 152, G Cot 100 and 241-4-2 (positive *gi* values) were also considered as grandparents in production of best three way cross combinations.

Positive and significant two line specific effects of first kind (*dij*) were observed in three crosses *viz.,* 241-4-2 × 65-2(s)- 3 (0.307), G Cot 100 × RFS 3438 (0.202) and Hyps 152 × Suvin (0.288) ,which would produce three way crosses with improvement in monopodia/plant when these parents are utilized as grandparents. For two line specific effects of the second kind, one combination 65-2(s) - 3 × 241- 4- 2(*sji*=0.217) was significant with positive effect. Parent 65-2(s)-3 as a grandparent and line 241-4-2 can be utilized as parent to produce significant three way crosses (Table 2). The reciprocal differences in the crosses indicates the presence of order effects in the three way crosses. Similar reports were published earlier by Ramalingam (1996) in cotton.

Positive and significant three line specific effects were exhibited by triplet 5 × 6 × 1 (Hyps 152 × Suvin × 241 -4- 2) (*tijk*=0.273) for this trait. The two line specific effect of first kind (*dij*) was positively significant in cross Hyps 152 × Suvin, hence the performance of this triplet was due to interaction of parent 241-4-2 as immediate parent crossed to grandparents. This

Table 1. Analysis of variance for fibre characters in cotton (mean squares)

S.	Source	*df*	Monopodia	Sympodia	Bolls/ plant	Mean squares				
						Boll weight (g)	Seed cotton yield (Kg/ha)	Seed index (g)	Lint index (g)	GOT
1	Replications	2	0.25 NS	67.40*	1175.77*	1.14 NS	23773.4*	0.09 NS	1.01 NS	0.66 NS
2	Gene line effect of first kind *(hi)*	5	0.34 NS	4.129*	84.91 NS	3.27*	7868.10*	3.57*	8.73*	4.24*
3	Gene line effect of second kind *(gi)*	5	0.95**	6.59*	334.30*	6.27*	10318.3*	6.72*	1.33*	26.10*
4	Two line specific effect of first kind *(dij)*	9	0.54**	4.16 NS	222.51*	0.839 NS	5149.25*	6.52*	2.01*	5.81*
5	Two line specific effect of second kind *(sij)*	19	0.15 NS	4.29 NS	113.89*	0.42 NS	2651.59*	3.02*	8.31*	3.62*
6	Three line specific effect *(tijk)*	21	1.13 NS	2.56 NS	139.70*	0.57 NS	2053.6 NS	2.36*	9.17*	7.80*
7	Crosses	59	0.27*	3.89 NS	151.72*	1.24*	3758.8*	3.45*	1.07*	7.54*
8	Error	118	0.15	4.83	46.73	0.46	1559.54	0.11	4.39	1.48
	CD (p=0.05)		0.64	-	13.19	1.09	70.45	0.55	0.33	1.96
	CV (%)		19.8	14.6	16.5	16.8	21.5	3.1	3.9	3.6

clearly indicated the parent order effects in which crosses will be effected to produce significant three way crosses .

Predominance of additive × dominance component epistatic gene action was observed for this trait with higher magnitude of additive × dominance genotypic variance(Table 3).

Sympodia/plant : Crosses 241-4-2 × G Cot 100 (*dij*=0.128) and RFS 3438 × Suvin (*dij*=1.125) had shown significant positive two line specific effects of first kind for number of sympodia per plant. These crosses would be utilized as grandparents to produce significant three way crosses for sympodia/plant. The highest three line specific effects was recorded in the triplet 1 × 5 × 2 (*tijk*=1.614). Estimation of three line specific effects (*tijk*) were found positive and significant for triplet 1 × 5 × 2 (1.614). Though the two line specific effect of first kind and second kind were non significant in three way cross 1 × 5 × 2, the three line specific effect was positively significant, which was due to inter action of all the parents. The results of components of genetic variance indicated that additive × dominance component of epistatic gene action was the highest followed by additive component. The rest of the variances were negative. Ramalingam (1996) and Patil *et al.*, (2005) reported additive × dominance followed by dominance × dominance gene actions in governing the character which are in agreement with present findings. Whereas Laxman and Ganesh (2003) reported dominance × dominance type of epistatic gene action in governing the character.

Bolls/plant : The general line effect of first kind (*hi*) and second kind (*gi*) for the character number of bolls per plant were positive and significant for parent Suvin (*hi*=4.944 and *gi*=3.167). Parent Suvin may be utilized as grandparent as well as a parent to produce significant three way crosses. RFS 3438 exhibited positive general line effect of first kind (*hi*) and parent, 241-4-2 had shown positive general line effect of second kind (*gi*). The preference for parental consideration was parent

Table 2. Estimation of General, Specific Line effects for diallel and triallel crosses which shown significance for the fibre characters in cotton

S no	Character	General line effects			Two line effects				Three line effects	
		Line	*hi*	*gi*	Cross	*dij*	*sij*	*sji*	Cross	*tijk*
									5x6x1	0.273*
1	Monopodia	Suvin	0.267*		241-4-2 x 65-2(s)-3	0.307*				
					G Cot 100 x RFS 3438	0.202*				
					Hyps 152 x Suvin	0.288*				
					65-2(s)-3 x 241-4-2			0.217*		
2	Sympodia				241-4-2 x G Cot 100	0.128*			1x5x2	1.614*
					RFS 3438 x Suvin	1.215*				
3	Bolls/plant	Suvin	4.944*	3.16*	241-4-2 x G Cot 100	8.46*			1x5x3	4.596*
					RFS 3438 x Hyps 152	3.7*			2x3x4	5.4*
					65-2(s)-3 x Suvin	4.1*			2x5x6	7.133*
					65-2(s)-3 x Hyps 152	4.138*			2x6x1	7.811*
					RFS 3438 x Suvin		3.234*		3x4x6	9.589*
					241-4-2 x Suvin		2.677*			
					G Cot 100 x 241-4-2			4.844*	3x6x1	5.878*
					65-2(s)-3 x RFS 3438			3.61*	4x5x1	10.656*
					Hyps 152 x G Cot 100			5.387*		
									5x6x2	5.911*
4	Boll weight (g)	241-4-2	0.292*		241-4-2xG Cot 100	0.325*			1x3x4	0.524*
		65-2(s)-2	0.22*		RFS 3438 x 65-2(s)-3	0.537*			3x4x2	0.684*
		Hyps 152		0.362*					3x5x6	0.645*
									4x6x5	0.552
5	Seed cotton) yield (Kg/ha	241-4-2	20.46*	14.82	241-4-2x G Cot 100	48.11*			1x3x5	34.50*
		Hyps 152		16.21*	65-2(s)-3 x Hyps 152	20.63*			4x5x1	26.59*
					RFS 3438 x Hyps 152	29.02*			5x6x4	27.73*
					65-2(s)-3 x RFS 3438			17.35*		
					Hyps 152 x G Cot 100			32.83*		

6	Seed index (g)	Hyps 152	0.206*		241-4-2x G Cot 100	1.103*	0.672*	1x3x5	1.273*
		Suvin	0.677*	0.655*	241-4-2x RFS 3438	0.302*	0.488*		
					241-4-2 x 65-2(s)-3	0.170*			
					G Cot 100 x Hyps 152	0.467*	0.165*		
					RFS 3438 x Suvin	0.280*	0.392*		
					65-2(s)-3 x Suvin	0.348*			
					Hyps 152 x Suvin	0.447*	1.311*		
					G Cot 100 x 65-2(s)-3		0.326*		
					65-2(s)-3 x Hyps 152		0.474*		
7	Lint index (g)	241-4-2	0.287*		241-4-2x G Cot 100	0.710*		1x2x3	0.264*
		G Cot 100	0.1402*	0.1138*	241-4-2x RFS 3438	0.115*		1x2x4	0.28*
		Suvin	0.0694*	0.2277*	241-4-2 x 65-2(s)-3	0.266*		1x3x5	0.78*
					G Cot 100 x Hyps 152	0.111*		1x5x2	0.424*
					RFS 3438 x 65-2(s)-3	0.145*		3x5x1	0.586*
					RFS 3438 x suvin	0.181*		3x6x2	0.546*
					Hyps 152 x Suvin	0.42*		4x5x3	0.602*
8	GOT	241-4-2	1.072*		241-4-2 x 65-2(s)-3	0.842*			
		G Cot 100	0.496*		G Cot 100 x 65-2(s)-3	0.821*			
		RFS 3438	0.404*		Hyps 152 x Suvin	1.038*			
		65-2(s)-3	0.600*		241-4-2x G Cot 100	1.029*			

Parents: 1.241-4-2; 2.G Cot 100; 3.RFS 3438; 4.65-2(s)-3; 5.Hyps 152; 6.Suvin

Suvin, as grand parent as well as parent whereas RFS 3438 as grand parent and 241-4-2 as a parent for crossing in production of significant crosses for the trait number of bolls per plant. Two line specific effects of first kind (*dij*) was positive and significant for crosses 241-4-2 × G Cot 100 (8.46), RFS 3438 × Hyps 152 (3.70), 65-2(s)-3 × Hyps 152 (4.31) and 65-2(s)-3 × Suvin (4.10) indicating that these combinations as grandparents would produce significant three way combinations. Line 65-2(s)-3 found to be a good grand parent than other genotypes as it exhibited significant crosses with two parents where as genotypes 241-4-2 and RFS 3438 with one parent each. The two line specific effect of second kind (*sij*) was positively significant in 241-4-2 × Suvin (2.677) and RFS 3438 × Suvin (3.234), hence parents 241-4-2 and RFS 3438 are proposed to be utilized as half parents (grand parents) to produce significant three way crosses with Suvin as a parent. Whereas the reciprocals were also significant in G Cot 100 × 241-4-2 (*sji*=4.844), 65-2(s)-3 × RFS 3438 (*sji*=3.61) and Hyps 152 × G Cot 100 (*sji*=5.387) indicating that lines G Cot 100, 65-2(s)-3 and Hyps 152 would also be utilized as half parent in addition to the above to produce significant three way crosses. In this case the reciprocals were considered as they are associated with order effects in three way cross hybrids. It was found to be interesting that many crosses had reciprocal differences for second kind effects indicating that the importance order of arrangement of parents in triplets.

The three line specific effects (*tijk*) were positive and significant in crosses *viz.*, 4 × 5 × 1 (10.656), 3 × 4 × 6 (9.589), 2 × 6 × 1 (7.811), 2 × 5 × 6 (7.133), 5 × 6 × 2 (5.9118), 3 × 6 × 1 (5.8788), 2 × 3 × 4 (5.4) and 1 × 5 × 3 (4.956). The triplet 4 x 5 x 1 (65-2(s)-3 × Hyps152 × 241-4-2) was the best in performance, due to the positive and significant two line specific effect of first kind (*dij*) in cross 65-2(s)-3 × Hyps 152 and the general line effect of 241-4-2. Parent 241-4-2 had positive *gca* effect for number of bolls per plant and which was proved as the best general combiner. Hence triplet 4 × 5 × 1 yielded best to produce a three way cross for bolls/plant. The alternative forms 1 × 4 × 5 and 1 × 5 × 4 had non significant *tijk* effects, clearly elucidated the order effect in which parents to be crossed.

Components of genetic variance for the trait indicated that the predominance of additive × dominance gene action followed by additive and dominance × dominance gene actions (Table 3). The epistatic component played major role than additive components in governing the character. Ramalingam (1996) reported similar results of additive × dominance gene action followed by dominance × dominance components of epistatic gene action. Patil *et al.,* (2005) also reported predominance of additive × dominance gene action which are in fully agreement with present results. Whereas Laxman and Ganesh (2003) reported predominance of dominance × dominance component of epistatic gene action in the inheritance of the character.

Boll weight (g) : The general line effects of first kind (*hi*) was positive and significant for parents 241-4-2 (0.292), 65-2(s)-3 (0.22) and second kind effect (*gi*) for Hyps 152 (0.362) (table. 2). The *gca* effects of diallel parents 241-4-2 and Hyps 152 were positively significant whereas in triallel, parents 241-4-2 and 65-2(s)-3 for general line effect of first kind and Hyps 152 for general line effect of second kind were found positively significant. This clearly indicated that parents 241-4-2, and 65-2(s)-3 were good general combiners to produce bigger bolls when used as grandparents, where as Hyps 152 as a parent (full parent) crossed to a single cross. The specific combining ability in diallel crosses was positively significant in crosses RFS 3438 × Suvin, 241-4-2 × RFS 3438 and RFS 3438 × Hyps 152.

The two line specific effects of first kind (*dij*) were positive and significant for crosses RFS3438 × 65-2(s)-3 (0.537) and 241-4-2 × G Cot 100 (0.325). These lines as grandparents will produce significant three way cross combinations. The two line specific effect of second kind (*sij*) was positive in seven crosses with reciprocal differences indicating the importance of parent order in three way crosses. The highest significant positive three line specific effects (*tijk*) were exhibited by 3 × 4 × 2 (0.684) followed by 3 × 5 × 6 (0.645), 4 × 6 × 5 (0.552) and 1 × 3 × 4 (0.524).

The triplet 3 × 4 × 2 (RFS 3438 × 65-2(s)-3 × G Cot 100) had shown highest positive significant three line specific effect for boll weight. The parent order 3 × 4 × 2 clearly elucidated the superior performance whereas its alternative forms, 2 × 3 × 4 and 2 × 4 × 3 had negative non significant *tijk* effects indicating the importance of order of parents to be used in three way crosses for obtaining highest gain in boll weight. The best triplet 3 × 4 × 2, parent 65-2(s)-3 was good general combiner whereas the other parents were poor general combiners. The two line specific effects of first kind were positively significant for RFS 3438 × 65-2(s)-3 as grandparents and the general line effect of second kind was positive for G Cot 100 which was the best choice as a parent to produce significant three way crosses. Thus the best performance can be attributed due to (i) *dij* effect (ii) *gi* effect and (iii) interaction of three parents used in particular order.

Additive × dominance gene action was predominant followed by additive and dominance × dominance components for inheritance of this trait (Table 3). It clearly revealed predominance of epistatic gene action playing major role in governing the character. Hence it is essential to go for two or three selections in segregating generations before starting selection for improvement of the character. Ramalingam (1996), Ganesh and Laxman (2003) and Patil *et al.,* (2005) reported predominance additive × dominance component followed by dominance × dominance of gene action for boll weight in cotton.

Seed cotton yield/plant (kg/ha) : The general line effects of first kind (*hi*=20.46) and second kind (*gi*=14.82) were positive and significant for parent 241-4-2 and parent Hyps 152 exhibited positive and significant general line effects of second kind (*gi*=16.213). These parents were good general combiners to produce best combination for seed cotton yield, while the parent 241-4-2 as grandparent as well as a

Table 3. Components of genetic variance for seed cotton yield and other characters

S. No.	Genetic variance	Mono-podia	Sym-podia	Bolls	Boll weight (g)	Seed cotton (Kg/ha)	Seed index (g)	Lint index (g)	GOT
σ^2a	-0.0457	0.1716	40.8917	0.6624	1108.23	1108.23	-0.0075	-0.1680	2.201
σ^2d	-0.2248	-6.8077	-276.0893	-0.0793	-5660.64	-5660.64	-6.2827	-0.7424	-9.010
σ^2aa	0.1498	-0.1189	-48.3335	-0.6712	-785.53	-785.53	0.1767	0.3867	-2.541
σ^2ad	0.4156	30.9391	1108.38	2.0758	25989.37	25989.37	19.7311	0.3055	30.426
σ^2dd	-0.1039	-7.8949	30.20	0.3815	-3787.35	-3787.35	2.0724	2.3575	10.897
σ^2a/σ^2d	-0.2032	-0.0252	-0.148	-8.353	-0.185	-0.185	-0.0011	-0.226	-0.244
σ^2d/σ^2a	-4.9190	-39.6719	-6.751	-0.1197	-5.107	-5.107	-837.69	-4.419	-4.093

parent in three way crosses, and Hyps 152 as a parent (full parent) to cross to a single cross to produce significant three way crosses. When *gca* effects of diallel and triallel analyses were compared, the parents 241-4-2 and Hyps 152 were positive and significant for seed cotton yield per plant. The specific combining ability of cross combination 241-4-2 × Hyps 152 was positively significant with highest *per se* performance for seed cotton yield (326.66g). This combination exhibited the best specific combining ability to produce high yielding F_1 hybrid.

Two line specific effects were positive and significant for crosses, 241-4-2 × G Cot 100 (*dij*=48.11) and 65-2(s)-3 × Hyps 152 (20.63). These lines in the crosses as grandparents will produce superior three way cross combinations. Positive and significant two line specific effects of second kind were observed for crosses RFS 3438 × Hyps 152 (*sij* = 29.02), Hyps 152 × G Cot 100 (*sji*=32.833) and 65-2(s)-3 × RFS 3438(*sji*=17.35) indicating that parents RFS 3438, Hyps 152 and 65-2(s)-3 would be utilized as half parents in three way crosses to produce significant three way crosses. It was clear that genotypes RFS 3438 and Hyps 152 were utilized as grandparents in the three way crosses for obtaining high performance than other genotypes. The best performing triplet 241-4-2 ×RFS 3438 × Hyps 152 (1 × 3 × 5) had the highest *tijk* effect of (34.50), followed by 5 × 6 × 4 (*tijk*=27.73) and 4 × 5 × 1 (*tijk* = 26.59) in terms of three line specific effects. The parent order effect in 1 × 3 × 5 clearly elucidated, the order of parents in which crossing may have to be effected. The other forms of the same triplets 1 × 5 × 3 and 3 × 5 × 1 were non significant, which clearly shows the order of parents playing an important role to obtain significant three way crosses. The best performance of this triplet (1 × 3 × 5) may be due to the parents 241-4-2 and Hyps 152 as best general combiners for first kind and second kind effects and positively significant for two line specific effect of second kind for the cross RFS 3438 × Hyps 152 (sij=29.02) and interaction of all the three parents might have produced highest yielding hybrid.

Components of genetic variance for this character showed additive × dominance type of gene action as predominant followed by additive component (Table 3). It was clearly understood that predominance of epistatic gene action plays an important role in governing the character. Similar results of predominance of additive × dominance followed by dominance × dominance gene actions was earlier reported by Ramalingam (1996).

Seed index (g) : General line effects of first kind (*hi*) was positive and significant for parent Hyps 152 (0.206) where as parent Suvin had exhibited positive and significant general line effects of first and second kind (*hi*=0.677; *gi*=0.665) for seed index(table 2). These parents were good general combiners to produce best combination for seed index when parent Hyps 152 was used as grand parent and Suvin as grand parent, as well as full parent.

The two line specific effects of first kind (*dij*) were positively significant for crosses 241-4-2 × G cot 100 (1.303), Hyps 152 × Suvin (0.447), 65-2(s)-3 × Suvin (0.348), 241-4-2 × RFS 3438(0.302), RFS 3438 × Suvin (0.280) and 241-4-2 × 65-2(s)-3 (0.170). These parents as grandparents produced superior three way crosses for seed index. Two line specific effects of second kind (*sij*) was found positive and significant in Crosses *viz.*, Hyps 152 × Suvin (*sij*=1.311), 241-4-2 × RFS 3438 (*sij*=0.488), G Cot 100 × 65-2(s)-3(*sij*=0.326),G Cot 100 × Hyps 152(*sij*=0.165), RFS 3438 × 65-2(s)-3(*sij*=0.392) and 65-2(s)-3 × Hyps 152(*sij*=0.474). Parents 241-

4-2, G Cot 100, RFS 3438, 65-2(s)-3 and Hyps 152 were utilized as half parents in three way crosses to produce significant crosses for seed index. In these lines, genotypes G Cot 100 and RFS 3438 were considered as one of the grand parents as they produced significant crosses with three other genotypes each, for the trait seed index. The presence of reciprocal differences was the clear cut indication of order effect of parents in three way crosses.

Triplet 1 × 3 × 5 (241-4-2 × RFS 3438 × Hyps 152) had the highest *tijk* effect and the grandparents of this cross were positively significant for two line specific effects of second kind and immediate parent Hyps 152 showed positive and significant general line effects of first kind. The parent order effect clearly elucidated in triplet 1 × 3 × 5 which had the highest significant positive three line specific effect (*tijk*). The order of mating of parental sequences is important to obtain high performing triplets for seed index. This clearly indicates the order effects of parents in which mating has to be done.

The components of genetic variance for the trait indicated that additive × dominance component was predominance followed by dominance × dominance and additive × additive. It means that non fixable epistatic gene action played a major role in governing the character. Hence, it is necessary to go for recurrent selection cycles with step by step improvement for two to three generations for improving the trait. Ramalingam *et al.,* (1996) and patil *et al.,* (2005) reported that seed index was predominantly under the control of additive × dominance followed by dominance × dominance which are in full agreement with present finding. Whereas Laxman and Ganesh (2003) reported dominance × dominance being highest followed by additive × additive and additive × dominance for this trait.

Lint index (g) : Both first and second kind general line effects were positive and significant for two parents, *viz.,* G Cot 100 (*hi*=0.1402; *gi*=0.1138) and Suvin (*hi*=0.0694; *gi*=0.2277), these genotypes utilized as grand parents as well as full parents would produce significant three way crosses for lint index. Parent 241-4-2 was positively significant for general line effect of first kind (*hi*=0.287) and parent 65-2(s)-3 for general line effect of second kind (*gi*=0.0935) suggesting that the former can be utilized as grand parent and the later one as half parent respectively. Parents G Cot 100 and Suvin were considered as the best lines to involve in crosses as grand parents as well as parents in production of superior crosses for the trait lint index. When *gca* of diallel and triallel crosses were compared parents 65-2(s)-3, Hyps 152 and Suvin found positive significant for lint index. In triallel analysis Suvin shown positively significance for both general line effects whereas parent 65-2(s)-3 for general line effects of second kind. Lines *viz.*, G Cot 100, Suvin, 65-2(s)-3, 241-4-2 and Hyps 152 were the best general combiners for lint index.

Two line specific effects of first kind (*dij*) shown positive and significance in seven crosses *viz.*, 241-4-2 × G cot 100 (0.7016), Hyps 152 × Suvin (0.42), 241-4-2 × 65-2(s)-3 (0.2666), RFS 3438 × Suvin (0.1816), RFS 3438 × 65-2(s)-3 (0.145), 241-4-2 × RFS 3438 (0.115) and G Cot 100 × Hyps 152 (0.1116). Parents 241-4-2 and RFS 3438 were considered as one of the parent as grand parents to produce significant crosses for the trait lint index when compared with other genotypes. In between these two lines parent 241-4-2 is the best parent as it already proved as good general combiner for general line effects of first kind. These parents exhibited significant crosses with three other parents whereas remaining genotypes with two other parents.

Three line specific effect was found to be positive and significant for twenty three crosses. Among them triplet 1 × 3 × 5 (*tijk*=0.78), 4 × 5 × 3 (*tijk*=0.6022), 3 × 5 × 1 (*tijk*=0.5866) and 3 × 6 × 2 (*tijk* = 0.5466) were the best for lint index (Table 4.40). The highest three line specific effect was recorded in triplet 1 × 3 × 5 where as highest *per se* performance was shown by 1 × 2 × 4.

In the case of the triplet 1 x 3 x 5 (241-4-2 × RFS 3438 × Hyps 152), the grand parents 1 × 3 recorded positive significance for two line specific effects of second kind (*dij*=0.115) and the interaction of second parent Hyps 152 contributed to the production of high performing triplet. The other forms of the triplet 3 × 5 × 1 had shown positive significant *tijk* effect where as triplet 1 × 5 × 3 had negative *tijk* effect. The best performance of triplet 1 × 3 × 5 may be due to positive significant two line effects of first kind in grandparents and interaction of second parent Hyps 152 and pooling up of favourable alleles.

Components of genetic variance for this trait revealed that dominance × dominance component of gene action was predominant followed by additive × additive and additive × dominance gene actions, indicating the predominant role of epistatic gene action in governing the character. Similar results reported by earlier workers, Ramalingam (1996) and Laxman and Ganesh (2003) who opined that dominance × dominance components of genetic variance was governing the character.

Ginning outturn : The general line effect of first kind (*hi*) was positive and significant for 241-4-2 (1.072), G Cot 100 (0.496) and RFS 3438 (0.404), these parents would be utilized as grand parents to produce significant three way crosses. The general line effect of that second kind (*gi*) was positive and significant for parent 65-2(s)-3 (0.600) that would be utilized as a parent (full parent) to cross to a single cross in three way crosses.

Two line specific effects of first kind (*dij*) was positive and significant in crosses Hyps 152 × Suvin (1.038), 241-4-2 × 65-2(s)-3 (0.842) and G Cot 100 × 65-2(s)-3 (0.821) these crosses would produce significant three way crosses when used as grand parents. Parents 241-4-2 and G Cot 100 were equally good with the parent 65-2(s)-3, while selecting parents for the crossing programme. The two line specific effects of second kind (*sij*) was positive and significant in the cross 241-4-2 × G Cot 100 (1.029) indicating the usefulness of utilizing the parent 241-4-2 as half parent to produce significant three way crosses for ginning out turn. Parent 241-4-2 must be taken into consideration for the crossing programme in order to improve ginning out turn as it proved as a good general combiner and as a grand parent. In single crosses 241-4-2 × Hyps 152 and RFS 3438 × Suvin had shown positive significant sca effects for ginning out turn.

Three line specific effects (*tijk*) was found to be positive and significant in thirteen crosses. Among them the triplet, 1 × 6 × 3 (1.813) has shown the highest performance, in which the parents 241-4-2 and RFS 3438 were the best general combiners to produce significant three way crosses. It clearly elucidated the order effect of parents in which crossing to be effected to produce significant triplets. The alternative triplets, 1 × 3 × 6 and 3 × 6 × 1, in which the earlier one had negative Tijk effects and latter had positive effect. This clearly indicates the order effects of parents in production of significant triplets. In this triplet 1 × 6 × 3 the best performance was due to positive interaction of specific combing ability effects of grandparents with that of parent RFS 3438.

The fixable component of epistatic gene action was playing major role in governing the character. Hence pedigree method of breeding may be followed for improvement of the character. Ramalingam (1996) reported predominance of dominance × dominance component followed by additive gene action for this trait in cotton which are in partial agreement with present findings. Laxman and Ganesh (2003) indicated the predominance of non fixable epistatic interactions (additive × dominance followed by dominance × dominance) governing the character which were not in agreement with the present findings .

Based on the above studies all the characters were mostly governed by additive × dominance gene action (epistatic component). Hence trait improvement would be possible by adopting heterosis breeding for development of F1 hybrids based on specific combining ability of parents. Purelines were isolated by adopting special breeding methods like inter mating in early segregating generations for two to three generations with step by step improvement followed by pedigree method of breeding or special breeding methods like biparental selection scheme and recurrent selection schemes.

REFERNCES

Laxman, S and Ganesh, M. 2003. Combining ability for yield components and fibre characters in cotton (*Gossypium hirsutum* L.). *Jour. Res. Acharya N. G. Ranga Agri. Uni.* **31** : 19-23.

Patil, A.J. Meshram, L.D and Sakhare, S.B. 2005. Triallel analysis for seed cotton yield in hirsutum cotton. *Jour. Maharastra Agri. Uni.* **30** : 15-18.

Ponnuswamy, K.N., Das, M.N. and Handoo, M.I. 1974. Combining ability analysis for triallel cross in maize (*Zea mays* L.). *Theriti. Appl. Gene.* **45** :170-75.

Ramalingam, A. 1996. Genetics of seed cotton yield and its components in upland cotton (*Gossypium hirsutum* L.).Diallel and triallel analysis. *Ph.D. Thesis, TAU.*

Rawlings, J.O. and Cockerham, C.C. 1962. triallel analysis. *Crop Sci.* **2** : 228-31.

Singh, R.K and Chaudhary, B.D. 1985. *"Biometrical Methods in Quantitative Genetic Analysis"*. Kalyani Publishers, New Delhi pp. 215-218.

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Genetic improvement for fibre quality traits in *arboreum* cotton

V.N. CHINCHANE

Vasantrao Naik Marathwada Krishi Vidyapeeth, Cotton Research Station, Parbhani 431401

E-mail : crsmb@rediffmail.com

ABSTRACT : Cotton is an inevitable source of natural fibre in the textile industry throughout the world. *G.arboreum* cultivars have inherent abillty of resistance against insect pests and diseases and withstand moisture stress. At the same time they have short and coarse fibre which is not suited for high speed spinning in modern textile industry. At Cotton Research Station Mahboob Baugh Farm,VNMKV Parbhani efforts have been made to develop high yielding *arboreum* strains having high fibre quality.

In the present investigation, fifteen newly developed strains of *arboreum* cotton were evaluated for yield and fibre quality traits along with checks *viz.,* PA 402, PA 08, and NH 615 under rainfed condition at Cotton Research Station Mahboob Baugh Farm,VNMKV Parbhani during *kharif* 2012-2013. The crop suffered due to moisture stress during vegetative and terminal growth stages. The strain PA 739 recorded highest seed cotton yield (1465 kg / ha) followed by PA 778 (1400 kg / ha) and PA 796 (1386 kg /ha). A range of 34.03 (PA 791) to 36.83 per cent (PA781) was observed for ginning outturn amongst the strains under testing.The strain PA 781 recored highest ginning outturn (36.83 %) followed by PA 778 (36.31 %). In quality paramenters, most of the newly developed strains are superior than the check varieties. In respect of fibre length measured as 2.5 per cent span length, all the strains except PA 739 were superior to the check varieties.The strain PA 789 had maximum fibre length (32.9 mm) followed by PA 794 (32.7 mm) and PA 795 (32.1 mm).With respect to fibre strength, all the strains were superior to check varieties. The strain PA 789 recorded highest fibre strength (24.5 g /tex) follwed by PA 788 (23.9 g /tex) and PA 794 (23.08 g /tex).Uniformity ratio ranged from 47 to 52. Micronaire vanue ranged from 4.1 to 5.5. Majority of the new genotypes showed distinct superiority for short fibre content over check varieties. Considering averall fibre quality parameters,genotypes PA 789 and PA 794 were found superior fibre quality traits.

Key word : *G.arboreum,* genetic improvement, fibre quality,

India practically grows all the four cultivated species of which diploid *G. arboreum, G.herbaceum* and tetraploid *G.hirsutum* are windely grown in most of the cotton growing states. Amongst the two cultivated diploid species *G. arboreum*, commonly known as *desi* cotton was predominantly under cutivation prior to the introduction of tetraploid *G.hirsutum* in states of Maharashtra ,Karnataka, Madhya Pradesh and Andhra Pradesh.The cultivation of varieties and hybrids of American cotton spread mainly because of their superior fibre qualities than desi cotton. *Desi* cotton though have high or comparable prductivity, wider adaptability and inherent ability to resist major pest and diseases, possessed inferior fibre qualities than american cotton .The american cotton being highly susceptible to major sucking pests and bollworms,the plant protection measures to control than have gone beyond the reach of marginal cultivators. Therefore, at Cotton Research Station, MB Farm, VNMKV, Parbhani efforts have been made to develop high yielding *arboreum* strains having high quality lint. In the present investigation new strains have been evaluated for yield and quality traits in comparison to cultivated varieties.

MATERIALS AND METHODS

In the present investgation fifteen newly developed strains of *arboreum* cotton were evaluated for yield and quality traits along with three check varieties *viz.,* PA 402, PA 08 and NH 615. Trial was conducted in randomized block design with three replications. Each strain was planted in 4 row plot of 5.4 meter length with a spacing of 45 x 22.5 cm. Sowing was done by dibbling method using 2 seeds/hill. Optimum plant stand was maintained by thinning of extra plants. Normal recommended agronomical package of practices were followed to raise the crop.Observations were recorded on seed cotton yield (on plot basis)and yield contributing traits (on five competitive plants taken randomly).Lint samples were sent to CIRCOT, Nagpur for evaluation of quality traits.Mean values were subjected to standard statistical analysis.

RESULTS AND DISCUSSION

Significant level of variability was observed for most of the traits studied in present material. To give more emphasis on quality

Table 1. Seed cotton yield ,accessory traits and fibre quality traits of *arboreum* cotton strains.

Sr. No.	Genotype	Seed cotton yield (kg/ha)	Lint yield (kg/ha)	Ginning Out-turn (%)	Boll wt (g)	2.5 per cent SL length	UR (%)	Fineness Microna 10-6 g /	Bundle	E1 strength Tenacity (g / tex) at 3.2 mm gauge	SFI (%)
1	PA 739	1465	522	36.09	2.78	27.3	51	5.4	22.9	5.2	10.2
2	PA 753	1162	402	34.96	2.64	29.9	51	5.0	21.1	4.8	6.9
3	PA777	1055	368	34.88	2.54	29.6	47	4.9	20.8	5.5	6.8
4	PA 778	1400	506	36.31	2.76	30.5	48	5.2	21.1	4.8	7.3
5	PA 781	1232	450	36.83	2.70	31.4	48	4.8	22.2	5.0	5.6
6	PA 788	1352	478	35.47	2.84	30.1	52	4.9	23.9	4.9	6.4
7	PA 789	898	298	33.45	2.60	32.9	50	4.3	24.5	5.3	5.0
8	PA 790	1120	380	34.07	2.64	29.5	49	4.8	21.6	5.4	6.9
9	PA 791	999	336	34.03	2.56	31.7	48	4.7	22.8	4.8	5.7
10	PA 792	1173	401	34.35	2.68	30.4	48	5.5	20.2	5.4	7.2
11	PA 793	1167	408	35.13	2.76	30.9	46	5.5	23.4	6.4	6.0
12	PA 794	1055	360	34.15	2.70	32.7	49	4.1	23.8	5.5	5.7
13	PA 795	1145	384	33.83	2.58	32.1	49	4.7	20.4	5.3	6.1
14	PA 796	1386	498	36.10	2.80	30.4	51	4.7	22.4	5.4	9.2
15	PA 797	1083	372	34.49	2.66	31.4	50	4.5	22.0	4.9	5.3
Checks49											
16	PA 402 (c)	1197	420	35.35	2.74	28.5	49	5.2	21.0	5.1	9.1
17	PA 08 (c)	1306	472	36.41	2.70	27.6	49	5.0	20.7	5.6	9.1
18	NH 615 (c)	1123	442	39.69	2.92	29.3	50	4.3	20.9	5.6	7.2
	SE±	24.69									
	CD (p=0.05)	73.58									
	CV(%)	4.94									

aspects, results on seed cotton yield, boll weight, ginning percent, lint yield in addition to quality parameters have been discussed.

Evaluation of high quality G. *arborum* genotypes for yield and yield contributing characters : Statistical analysis of variance for seed cotton yield revealed the significant differences among the genotypes. Highest seed cotton yield was recorded by PA 739 (1465 kg/ ha) followed by PA 778 (1400 kg / ha) and PA 796 (1386 kg/ ha) which were at par among themselves but significantly superior over all the genotypes and check.The maximum lint yield was recorded by PA 739 (522 kg /ha) followed by PA 778 (506 kg / ha) and PA 796 (498 kg/ ha). The highest boll weight was recorded by PA 788 (2.84 g) followed by PA 796 (2.8 g) and PA 739 (2.78g). A range of 34.03 (PA 791) to 36.83 per cent (PA781) was observed for ginning outturn amongst the strains under testing.The strain PA 781 recored highest ginning outturn (36.83 %) followed by PA 778 (36.31 %) and PA 796 (36.10 %).

Evaluation of high quality *G. arborum* genotypes for fiber quality: In quality paramenters, most of the newly developed strains are superior than the check varieties. In respect of fibre length measured as 2.5 % span length, all the strains except PA 739 were superior to the check varieties.The strain PA 789 had maximum fibre length (32.9 mm) followed by PA 794 (32.7 mm) and PA 795 (32.1 mm).With respect to fibre strength, all the strains were superior to check varieties. The strain PA 789 recorded highest fibre strength (24.5 g / tex) follwed by PA 788 (23.9 g /tex) and PA 794 (23.08 g /tex). Uniformity ratio ranged from 47 to 52.In case of uniformity ratio, genotypes PA 789, PA 797, and PA 796 were found excellent. Micronaire value ranged from 4.1 to 5.5.The genotypes PA 794 and PA 789 were having fine fibre. The elongation percentage ranged from 4.8 to 6.4. Majority of the new genotypes showed distinct superiority for short fibre content over check varieties. On overall basis the best entries in respect of fibre quality were observed to be PA 789 and PA 794.Our results are in confirmity with the findings of Jain (1996), Patil *et al.,* (1988), Kumar *et al.,* (2003) and Yadava *et al.,* (2000) were having similar findings for quality traits.

REFERENCES

Deshpande L.A. Deosankar D.B. and Deshmukh D.C. 1991. Combining ability analysis for economic traits in interspecific cross of *desi* cotton *ISCI Journal,* **16** :19-26

Jain, S. 1996. Heterosis for fibre characters in intra and inter specific hybrids of cotton. *J. Cotton Res.Dev.***10** :147-49**.**

Kulkarni V.N. , Khadi B. M.,Deshpande L.A,Sreenivasan S and Bisankopp M. S. 2003 Hirsutisation of diploid cultivated cotton. Proceedings of *"World Cotton Research Congress-3"*, Cape Town,South Africa , pp 85-94

Kumar, Manoj, Chhabra, B.S. and Kumar, Ramesh 2003. Heterosis for seed cotton yield and fibre quality characters in intra *G. hirsutum* hybrids. *J. Cotton Res. Dev.* **17 :**27-29.

Patil, F.B., Thombre, M.V. Shinde, Y.M. and Darade, R.S. 1988. Heterosis in fibre propreties of cotton under multiple environments. *J.Maharashtra Agric. Univ.* **13 :** 277-80**.**

Pole, S.P., Sudewad, S.M Kamble, S.K. and Borgaonkar, S.B.2008. Heterosis for seed cotton yield and yield components in upland cotton (*Gossypium hirsutum* L.). *J Cotton Res. Dev* **22 :** 139-42.

Shastry, P.P. and Tomar D.S. 2004. Screening of *hirsutum* genotypes against major cotton diseases under natural field conditions.Proceeding of International Symposium on *"Strategies for Sustainable Cotton Production –A Global Vision 3"* USA, Dharwad November ,23-25 Crop Protection . PP 375-76

Yadaava O.P, Lather B.P.S. and Dhayia B.N. 2000 Studies on variability, correlation and path analysis in desi cotton (*Gossypium arboreum* L.) *J.Cotton Res. Dev.* **14** : 143-46.

Multivariate analysis of genetic diversity in upland cotton (*Gossypium hirsutum* L.)

S. PRADEEP AND Y. SATISH

Department of Genetics and Plant Breeding, Acharya N.G. Ranga Agricultural University, Bapatla-522 101

E-mail: pradeep.seepana @gmail.com

ABSTRACT : Genetic divergence was carried out with sixty genotypes of upland cotton based on 15 characters using Mahalanobis' D^2 statistic and principal component analysis. On the basis of D^2 statistic 60 genotypes were grouped into 11 clusters indicating that the genetic diversity and geographical diversity were not related and PCA identified seven principal components which explained 78.696 variability in upland cotton. The PCA enabled loading of similar type of variables on a common principal component. Divergence studies indicated that geographical diversity is always not necessarily associated with the genetic diversity. Multivariate analysis revealed maximum divergence among HYPS 152, GISV 267, MCU 5, L 389 and TCH 1741 signifying their role in exploitation of heterosis.

Key words: genetic divergence, D^2 analysis and Principal Component Analysis

Cotton is the king of apparel fibres, since times immemorial popularly called as "White Gold" has played a pivotal role in the history and civilization of mankind. It alone accounts for 70 per cent of total fibre consumption in textile sector with approximately 38 per cent of the country's export.The diversity of parents is of prime importance, since the crosses made between the genetically divergent parents are likely to throw desirable recombinants in the progenies. The present study was carried out with two methods of clustering based on D^2 analysis and principal component analysis. Mahalanobis' D^2 statistic is an effective tool in quantifying the degree of genetic divergence at genotypic level and provides quantitative measure of association between geographic distribution and genetic diversity based on generalized distance and principal component analysis was carried out to transform the inter dependent traits into a set of independent traits as well as to reduce the dimensionality of the data structure (Banfield, 1978). The present investigation is an attempt to study genetic divergence in 60 genotypes of upland cotton using multivariate analysis.

MATERIALS AND METHODS

The present study was carried out with 60 genotypes of cotton (*Gossypium hirsutum* L.) obtained from different research centres across the country in randomized block design with three replications at Regional Agricultural Research Station, Lam Farm, Guntur, Andhra Pradesh during *kharif* 2014-2015. The inter- and intra-row spacing adapted was 105 x 60cm. Each plot consisted of one row of 6m length and observations were recorded on five randomly selected plants from each genotype per replication for characters *viz.,* plant height (cm), Days to 50 per cent flowering, number of monopodia/plant, sympodia/plant, bolls/plant, boll weight (g), seed index (g), lint index (g), micronaire (10^{-6}g/in), bundle strength (g/tex), lint yield/plant (g) and seed cotton yield/plant(g). Ginning outturn (%), 2.5 per cent span length (mm) and uniformity ratio were recorded on plot basis. The fibre quality characters were analyzed at CIRCOT regional unit Lam, Guntur. The data were statistically analyzed to study diversity by Mahalanobis' D^2 statistic and principal component analysis (PCA) as described by Jackson (1991).

RESULTS AND DISCUSSION

On the basis of D^2 values the sixty genotypes were grouped into 11 clusters (Fig. 1), out of which cluster I was the biggest cluster with 34 genotypes followed by clusters II and III which consisted of nine genotypes each while, the remaining clusters *i.e.,* cluster III consisted of single genotype as shown in Table 1.

The percent contribution towards genetic divergence was maximum by 2.5 per cent span length (18.14) followed by seed index (17.57), days to 50 per cent flowering (13.62), micronaire (10.56), monopodia/plant (10.45), bundle strength (8.02), bolls/plant (6.1), seed cotton yield/plant (5.48), plant height (4.41), boll weight (1.86), lint index (1.41), lint yield/plant (1.19), uniformity ratio (0.68), ginning outturn (0.34) and sympodia /plant (0.17) as shown in Table 2.

The maximum intra cluster distance was observed for cluster III (35.23) followed by cluster II (31.03) and cluster I (24.95), while, it was zero for clusters IV, V, VI, VII, VIII, IX, X and XI as shown in Table 3. The high intra cluster distance in cluster III indicates the presence of wide genetic diversity among the genotypes present within this cluster.

The inter cluster distance was maximum between cluster IX and X (185.35), followed by cluster X and XI (177.20), cluster VII and XI (122.06), cluster VIII and X (115.83), cluster V

Table 1. Clustering pattern of 60 cotton (*Gossypium hirsutum* L.) genotypes by Tocher's method.

Cluster No.	No. of genotypes	Name of the genotype
I	34	SCS 1002, CNH 120 M/B, BS-3, GJHV 511, CCH 11-2, ARBH 701, RAH 1066, PRAMUK, GJHV 375, GJHV 02145, L 808, CCH 1831, RB 57, AKALA 15-77 D, CNH 19, CCH 11-1, P 5629, H 1300, SCS 1211, ARBA 271, KH 1101, TSH 04/115, CNH 44, HS 293, L 1058, RHC 0811, CNH 1116, NDLH 1938, NH 644, 241-2-4, L 804, DS 56, GJHV 516, BJA 592
II	9	SCS 1001, HS 292, KH 1301, SCS 1210, ARBH 1301, CPD 1301, L 1801, SCS 1214, HAG 1055
III	9	RSA 2455, H 7, TSH 0499, H 1442, TCH 1741, MCU 5, LH 2256, CPD 1302, L 1011
IV	1	CNH 50
V	1	IH 615
VI	1	L 604
VII	1	TCH 1705
VIII	1	GISV 267
IX	1	HYPS 152
X	1	IH 65
XI	1	L 389

Table 2. Contribution of different characters towards genetic divergence in 60 cotton genotypes.

Character	Contribution towards divergence (%)	Times ranked first
Plant height (cm)	4.41	78
Days to 50 per cent flowering	13.62	241
Monopodia/plant	10.45	185
Sympodia/plant	0.17	3
Bolls/plant	6.1	108
Boll weight (g)	1.86	33
Ginning out-turn (%)	0.34	6
Seed index (g)	17.57	311
Lint index (g)	1.41	25
2.5 per cent span length (mm)	18.14	321
Micronaire (10^{-6}g/in)	10.56	187
Bundle strength (g/tex)	8.02	142
Uniformity ratio	0.68	12
Seed cotton yield/plant (g)	5.48	97
Lint yield/plant (g)	1.19	21

Table 3. Average intra and inter cluster D^2 values among 11 clusters in 60 cotton genotypes

Cluster No	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	**24.95 (4.99)**	36.11	44.31	35.50	39.20	32.89	54.01	60.22	55.00	71.39	67.87
II		**31.03 (5.57)**	59.14	47.71	41.25	56.21	47.40	46.12	66.54	67.14	96.02
III			**35.23 (5.94)**	72.00	61.17	51.30	101.74	55.47	69.07	96.15	69.18
IV				**0.00 (0.00)**	14.84	32.80	32.58	100.36	99.37	39.77	95.15
V					**0.00 (0.00)**	53.87	41.62	83.04	110.20	25.77	104.69
VI						**0.00 (0.00)**	64.72	91.44	63.98	99.52	73.68
VII							**0.00 (0.00)**	91.50	90.11	70.71	122.06
VIII								**0.00(0.00)**	59.03	115.83	87.48
IX									**0.00 (0.00)**	185.35	27.69
X										**0.00 (0.00)**	177.20
XI											**0.00 (0.00)**

Note: Bold and diagonal values indicate intra-cluster D ^{2} distance; figures in parentheses are D values

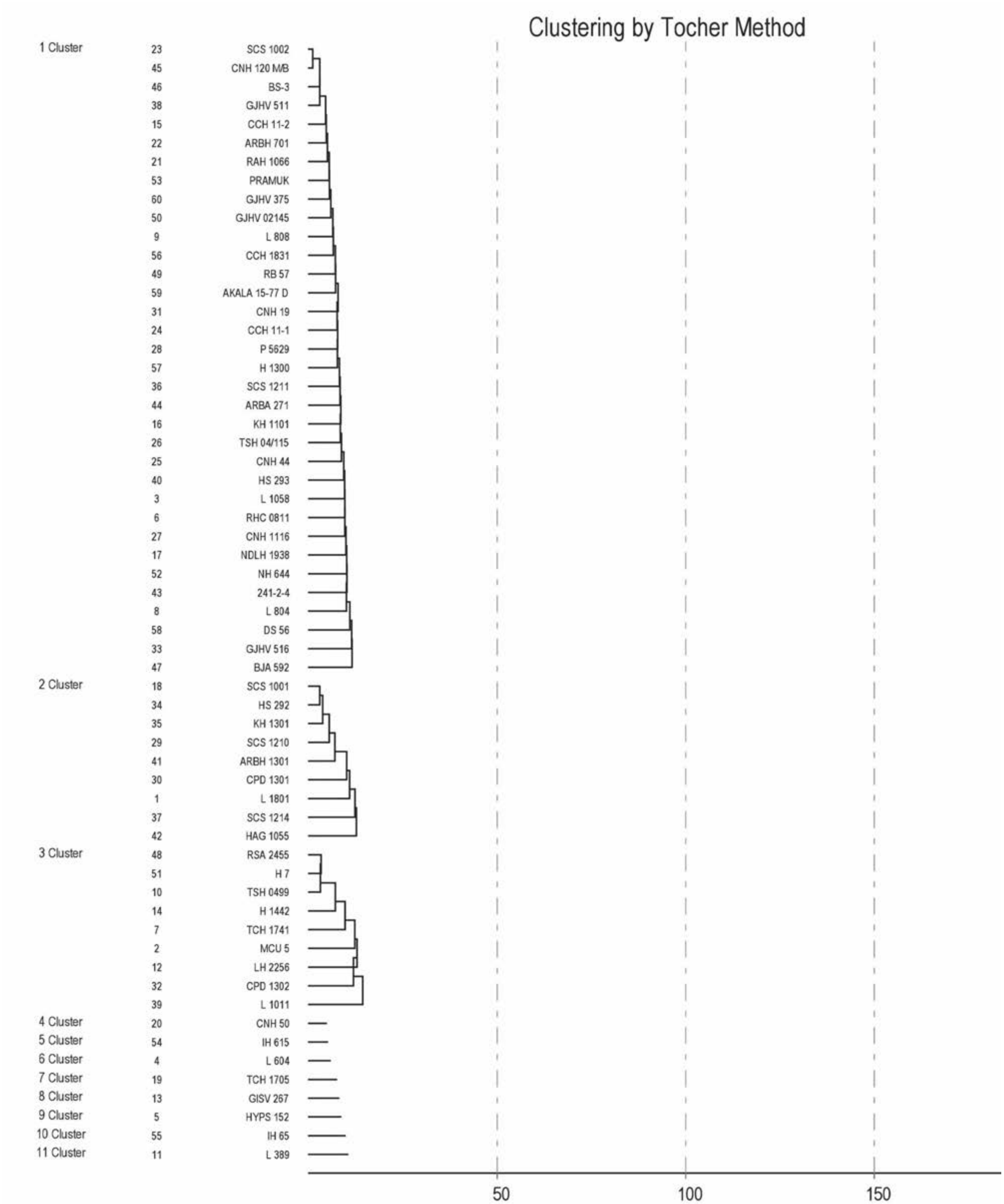


Fig. 1. Dendrogram showing relationship among 60 cotton (*Gossypium hirsutum* L.) genotypes in eight clusters based on Mahalanobis' D^2 values.

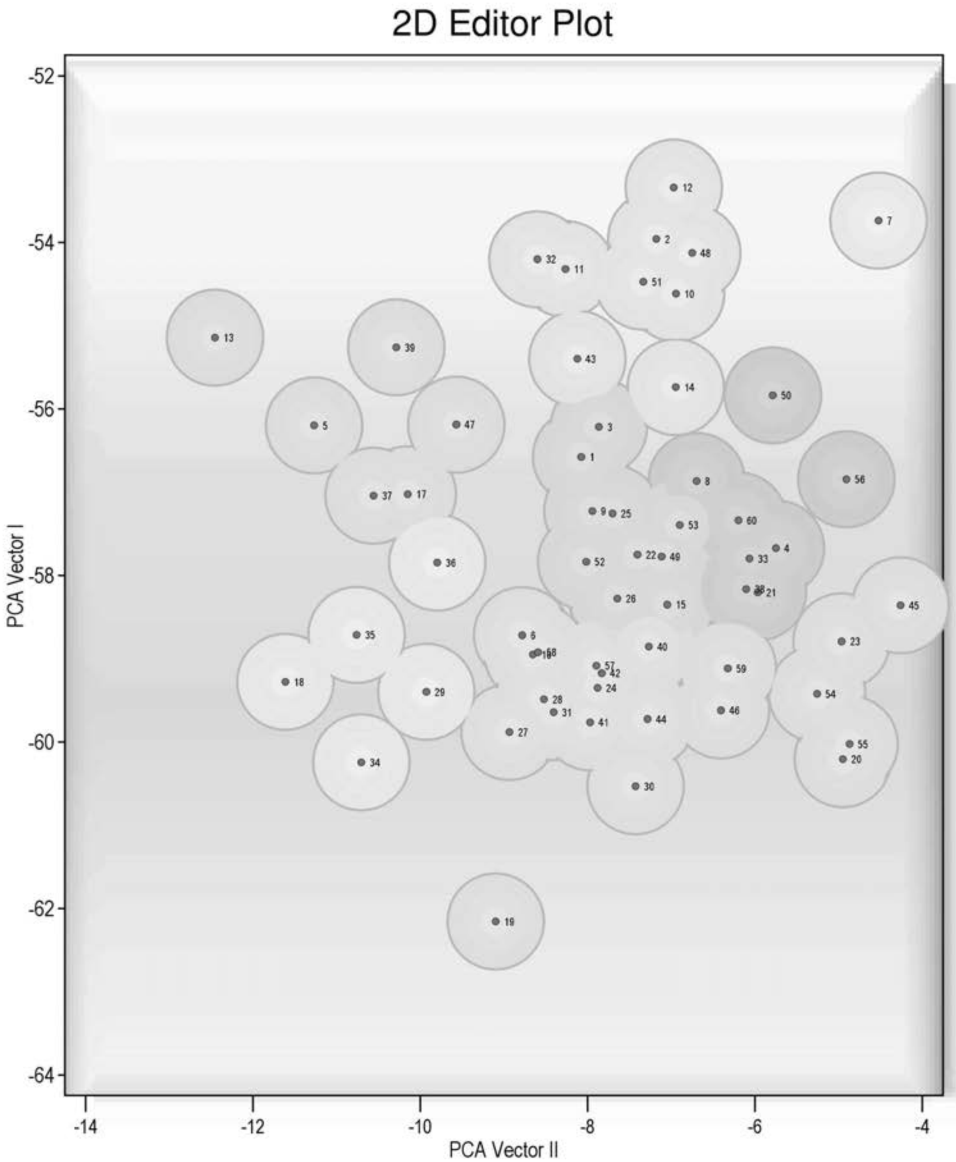


Fig. 2. Two dimensional graph showing relative position of 60 cotton(*Gossypium hirsutum* L.) genotypes based on PCA scores**.**

and IX (110.20), cluster V and XI (104.69), cluster III and VII (101.74) and cluster IV and VIII (100.36). This suggested that there is wide genetic diversity between these clusters. Based on these studies crosses can be made between genotypes of these clusters to obtain desirable transgressive segregants.

By Mahalanobis' D^2 statistic, it could be inferred that based on intra-and inter-cluster distance among the groups, it is suggested to make crosses between the genotypes of cluster IX (HYPS 152) and cluster X (IH 65), between genotypes of cluster X (IH 65) and cluster XI (L 389), between the genotypes of cluster VII (TCH

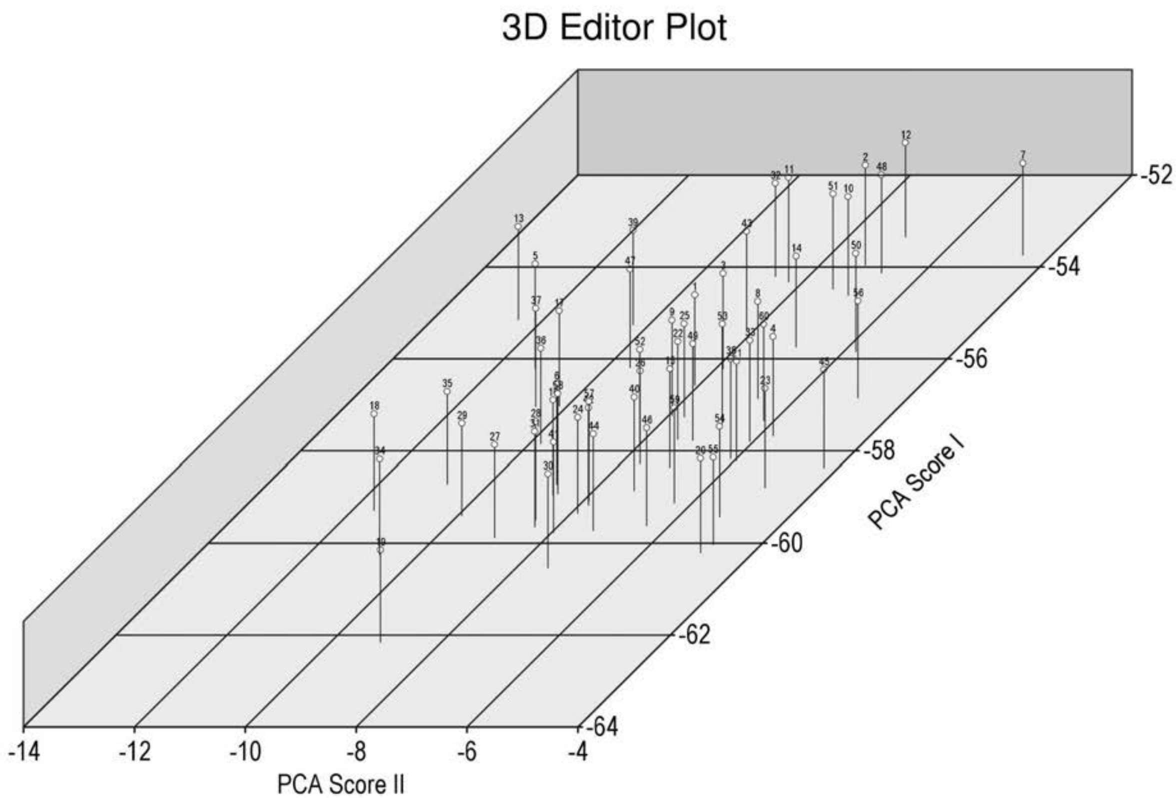


Fig. 3. Three dimensional graph showing relative position of 60 cotton (*Gossypium hirsutum* L.) genotypes based on PCA scores.

1705) and cluster XI (L 389), between the genotypes of cluster VIII (GISV 267) and cluster X (IH 65) after confirming their general combining ability.

Principal component analysis identified seven principal components (PCs), which contributed 78.696 per cent of cumulative variance. The first principal component contributed maximum towards variability (19.33) followed by PC_2 (16.04), PC_3 (11.476), PC_4 (10.616), PC_5 (8.959), PC_6 (7.095) and PC_7 (5.177) as shown in Table 4. The significant factors loaded in PC1 towards maximum genetic divergence were plant height, ginning outturn, lint yield/plant, bolls/plant, 2.5 per cent span length, seed index, lint index, monopodia/plant, days to 50 per cent flowering, seed cotton yield/plant, sympodia/plant and boll weight. 2D and 3D graphs (Fig. 2, 3) showed wide divergence between GISV 267, MCU 5, HYPS 152, TCH 1741, CNH 120 M/B, LH 2256 and IH 65 signifying their usefulness in cotton breeding to develop high heterotic hybrids.

General notation exists that the larger is the divergence between the genotypes, the higher will be the heterosis. Therefore, it would be desirable to attempt crosses between the genotypes belonging to distant clusters for getting highly heterotic crosses which are likely to yield a wide range of segregants on which selection can be practiced.

Table 4. Eigen values, proportion of the total variance represented by first seven principal components, cumulative per cent variance and component loading of different characters in cotton (*Gossypium hirsutum* L.).

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
Eigene Value (Root)	2.90	2.41	1.72	1.59	1.34	1.06	0.78
per cent Var. Exp.	19.33	16.04	11.48	10.62	8.96	7.10	5.18
Cum. Var. Exp.	19.33	35.37	46.85	57.46	66.42	73.52	78.70
Plant height (cm)	0.38	0.11	0.17	0.18	0.31	0.24	0.37
Days to 50 per cent flowering	0.10	-0.33	0.26	-0.43	-0.07	0.18	0.19
Monopodia/ plant	0.22	0.28	-0.34	-0.31	-0.20	0.22	0.11
Sympodia/ plant	0.05	-0.04	0.12	-0.52	0.31	0.05	-0.43
Bolls/ plant	0.27	0.34	0.05	0.07	0.53	-0.02	0.10
Boll weight (g)	0.03	-0.15	-0.15	0.50	-0.10	0.41	-0.02
Ginning outturn (%)	0.31	-0.35	-0.18	0.03	0.05	0.27	-0.12
Seed index (g)	0.26	-0.34	-0.37	0.05	0.19	-0.03	-0.24
Lint index (g)	0.26	-0.22	-0.14	0.11	0.24	-0.63	-0.10
2.5 per cent Span length (mm)	0.27	-0.16	0.35	0.27	-0.35	-0.13	-0.22
Micronaire (10g/inch)	-0.47	-0.12	-0.29	0.02	0.11	0.07	-0.17
Bundle Strength (g/tex)	-0.14	-0.34	-0.35	-0.09	0.18	0.04	0.46
Uniformity ratio	-0.29	-0.23	0.23	0.08	0.15	-0.26	0.39
Seed cotton yield/ plant(g)	0.09	-0.40	0.32	-0.12	-0.03	0.15	0.06
Lint yield/ plant (g)	0.30	0.03	-0.28	-0.19	-0.43	-0.33	0.29

The genotypes HYPS 152, GISV 267, MCU 5, L 389 and TCH 1741 showed maximum inter-cluster distance in Mahalanobi's D^2 analysis, principal component analysis and also have better per se performance in sympodia per plant, number of bolls per plant, boll weight, seed index, lint index and quality characters. So they can be exploited for the development of heterotic hybrids in future breeding programmes.

Selection of parents for hybrid breeding programme is of prime importance in the utilization of heterosis. For obtaining hybrids with high level of heterosis a question generally arises regarding the ideal distance (degree of divergence) at phenotypic level. Arunachalam and Bhandopadhyay (1984) have proved experimentally more number of heterotic combinations with higher level of heterosis was from the parents grouped into moderate divergent groups. Hence, selection of varieties should be more dependent on genetic diversity than the geographical diversity. Similar findings were also reported by Muraleedhar *et al.,* (2005) and Karunakar Raju *et al.,* (2005).

Two methods of grouping revealed the single concept of non correspondence of genetic divergence and geographical diversity. In a broad sense all the three methods of classifying genotypes into different groups is equally useful but hierarchical cluster analysis gave an additional advantage of identifying sub-cluster of the major groups at different levels so that small group can be critically analysed.

LITERATURE CITED

Arunachalam, V. and Bhandopadhyay, V.A. 1984. Limits to genetic divergence for occurrence of heterosis- experimental evidence from the crop plants. *Ind. Jour. of Gene. Plant Breed.* **44** : 548-54.

Banfield, C.F. 1978. Principal component analysis for genstat. *Jour. Stat. Comp. Simul.* **6** : 211-22.

Jackson, J.E. 1991. *A User's Guide to Principal Components.* John Wiley and Sons Inc., New York.

Karunakar Raju, G.B., Chenga Reddy, V. and Panduranga Rao, C. 2005. Multivariate analysis of genetic diversity in upland cotton (*Gossypium hirsutum* L.). *Andhra Agricul. Jour.* **52** : 66-74.

Muraleedhar, S.A., Murthy, J.S.V.S., Rama Kumar, P.V. and Srinivasa Rao, V. 2005. Mahalanobis' D^2 and principal component analysis of genetic diversity in tetraploid cotton (*Gossypium hirsutum* L.). *Andhra Agricul. Jour.* **52** : 99-104.

Genetic variability studies in *Gossypium spp* for the development of superior fibre quality lines

N. KANNAN, R. KRISHNAMOORTHY, K. RAMYA, P. KARTHIKEYAN, R.SELVAKUMAR AND K. SARAVANAN

Department of Genetics and Plant Breeding, Annamalai University, Chidambaram - 608 002

E-mail : kannan@rasiseeds.com

ABSTRACT : The present investigation on cotton (*Gossypium* spp) were undertaken to study the variability, heritability and genetic advance in the interspecific crosses of cotton to develop superior long staple and high fibre strength lines with *G. hirsutum* background by introgression of *G. barbadense* line. One backcross generation BC I (CG64 × (CG64 × CG45SB)) and two modified backcross generations namely, MBC I (CG67 × (CG64 × (CG64 × CG45SB)) and MBC II (CG92 × (CG64 × (CG64 × CG45SB)) were developed for line development programme. High heritability and high genetic advance were observed for span length and fibre strength in most of the generations of all the three crosses. This indicates the preponderance of additive gene action in the inheritance of this traits and offers the scope for improvement through simple selection procedures. In the present study, long staple (28.5-31.3 mm) with high fibre strength (28.9-33.1 g/tex) line with *hirsutum* background were obtained in the back cross I populations. Similarly in modified back cross I, long and extra-long staple (32.1-34.5mm) lines with high fibre strength (28.9-31.3g/tex) and in modified backcross II, long and extra-long staple (30.9-33.5mm) lines with high fibre strength (29.7-33.2g/tex) with recurrent plant background were obtained. The fibre quality parameters were assessed by SITRA fibre testing lab in ICC mode and confirms the findings of the present study.

Cotton 'King of Fibre' is the most important natural textile fibre and the sixth largest vegetable oil source in the world, and it is the cornerstone of textile industries worldwide (Ulloa *et al.,* 2006). In the agro based industry economy of the country cotton, the 'White Gold' enjoys a pre eminent status among all the commercial crops by providing livelihood to nearly sixty million people and is an important agricultural commodity providing remunerative income to millions of farmers both in developed and developing countries.

A long term challenge faced by cotton breeders is the simultaneous improvement of yield and fibre quality to meet the demands of the cotton cultivators as well as the modernized textile industry. Although fibre production has greatly increased, rapid development in the modern textile industry requires cotton fibre of higher quality. Because of competition in the global economy, yarn and textile manufacturers have adopted more efficient production machinery capable of generating more products per unit of time. Thus, the widespread use of high speed spinning technology has increased the demand for raw cotton fibre with higher strength. Hence, cotton fibre quality must be improved to remain competitive with synthetic fibres and to meet the needs of new spinning and weaving methods. Besides fibre strength, fibre length and fibre fineness are the primary qualities that influence textile processing (Kohel, 1999).

The tetraploid species *viz*., *G. hirsutum* L. and *G. barbadense* L. accounted for 90 per cent and 8 per cent of the world cotton production

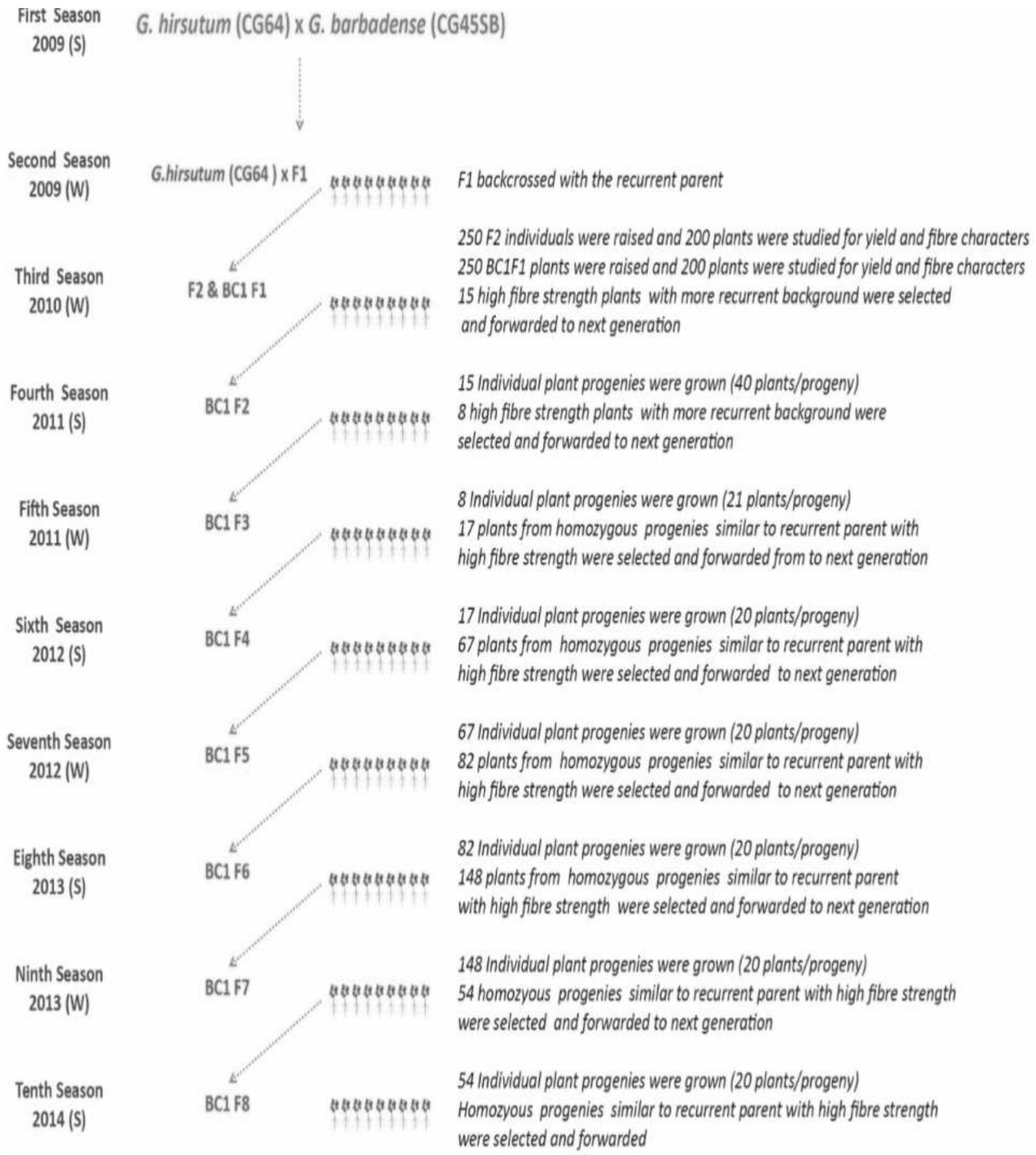
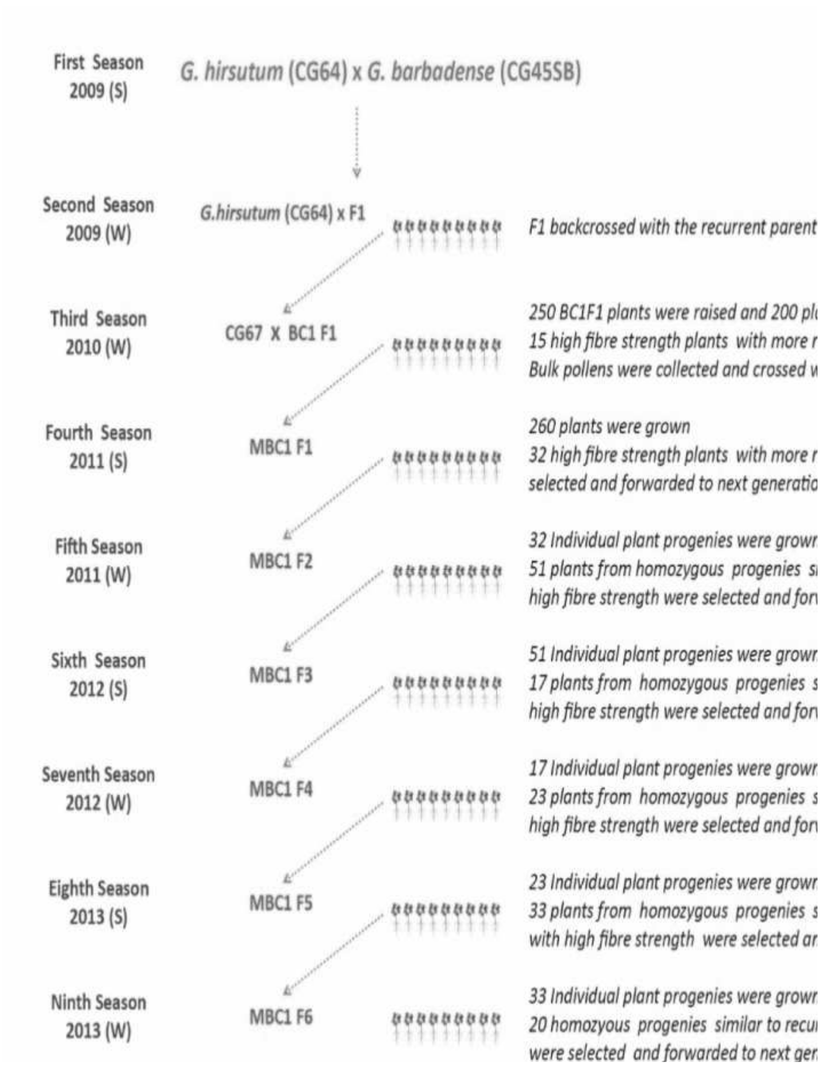


Figure 1. The breeding scheme for Backcross I programme

respectively (Zhang *et al.,* 2008). Soregaon *et al.* (2007) stated that interspecific hybrids in cotton have better performance compared to non-hybrid for fibre yield, ginning efficiency, fibre length, fibre fineness and fibre uniformity. The yield of interspecific hybrids is comparable with *G. hirsutum* L., whereas the fibre properties (length, fineness and strength) to *G. barbadense* L. (Davis, 1978).

Creating genetic variability is pre-requisite for plant breeders to exercise selection, as a part of continuous variation is due to heredity. The phenotypic and genotypic coefficients of variation were estimated using genotypic and phenotypic variances respectively. The coefficient of variation indicates only the extent of variability existing for various traits, but does not give any information about the



heritable portion of it. Therefore, heritability accompanied by estimates of genetic advance and genetic advance as per cent mean were also estimated.

Heritability in itself provides no indication about the genetic progress that would result from selection. However, at a fixed selection pressure, the amount of advance varies with magnitude of heritability. Genetic advance in a population cannot be predicted from heritability alone, the genetic gain for specific selection pressure has to be worked out. Many investigations had been made on heritability for seed cotton yield and other traits. Basbag and Gencer (2004) indicated that seed cotton weight per boll and 100 seed weight had high heritability; bolls per plant had low heritability, while other characters had moderate heritability. The characters with high heritability suggested some possibilities in obtaining required genotypes by selection in early segregating generations (F2, F3); while

selection for improvement was delayed due to low heritability for some characteristics. Basal and Turgut (2005) mentioned that moderate heritability estimates were observed for earliness ratio (0.53), fiber strength (0.50) seed cotton weight/boll (0.42) and lint per cent (0.40), however, bolls/plant and seed cotton weight/ plant showed low heritability estimates, 0.33 and 0.22, respectively.

MATERIALS AND METHODS

The present scientific studies on cotton (*Gossypium* spp) were conducted in the Rasi Research farm, Attur, Tamil Nadu. These studies were taken up to develop high fibre quality lines using cultivated tetraploid genotypes of upland cotton (*G. hirsutum*) namely CG 64, CG67 and CG 92 and Sea Island cotton (*G. barbadense*) namely CG45SB were crossed during 2009 summer. Three cross combinations were obtained namely, one backcross generation BC I (CG64 × (CG64 × CG45SB)) and two modified backcross generations MBC I (CG67 × (CG64 × (CG64 × CG45SB)) and MBC II (CG92 × (CG64 × (CG64 × CG45SB)). The schematic picture of breeding scheme, number of plants raised and number of plants selected in each generation of backcross I and modified backcross I and II are shown in Figs. 1 to 3 respectively. The backcross populations were evaluated for productivity and fibrequality parameters realizing the emphasis laid on developing ELS (Extra Long Staple and high fibre strength lines.

Each replication consists one row of P_1, P_2 and F_1. B_1 and F_2 were raised each in 20 rows and 5 rows of two different recurrent parents. The spacing adapted was 120 × 60 cm. Recommended agronomic practices and need based plant protection measures were followed under irrigated condition to obtain good crop stand. The experiments were raised in the winter (August – February) and summer (January to July) seasons. Selected plants in each single plant progeny were observed and their biometrical and fibre quality traits were recorded. The fibre quality traits were estimated by High Volume Instrument USTER® HVI Spectrum in ICC mode.

The mean and variances were analysed based on the formula given by Singh and Chaudhary (1977). The genotypic and phenotypic coefficient of variation was computed according to Burton and Devane (1953). The extent of genetic advance to be expected from selecting five per cent of the superior progeny was calculated using the following formula (Robinson *et al*., 1955). Heritability measures the relative amount of the heritable portion of variability and provides useful information for effective selection. The ration of the total genetic variation to the total phenotypic or observed variation is termed as co-efficient of heritability in broad sense whereas the ratio of the additive genetic variation to the total observed variation is called the co-efficient of heritability in the narrow sense.

RESULTS AND DISCUSSIONS

The mean, variance and coefficient of variance based on the data of individual plant observation for 11 characters were presented in the Table 1, 2 and 3 for back cross population I, modified backcross populations I and modified backcross populations II respectively.

Among the parents, mean performance of the parent P_2 was higher than P_1 in all yield contributing characters *viz.,* number of bolls per plant, boll weight, seed cotton yield, ginning per cent and lint index, whereas for fibre quality characters namely, 2.5 per cent span length and

Table 1. Estimates of variability, heritability and genetic advance as per cent of mean in backcross population - I

Season	Particulars		Bolls / plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2010 (W)	CG 45SB (P_1)	Mean	45.3	2.9	120.4	26.5	5.3	12.4	38.9	45.1	33.4	2.9	5.4
		Range	35.0 -56.0	2.4-3.2	102.3 -134.6	24.6-27.5	4.9-5.5	11.2-12.9	37.6-39.8	44.2-46.1	32.2-34.6	2.4-3.1	5.1-5.7
	CG 64(P_2)	Mean	76.8	4.4	182.7	35.5	5.4	10.5	30.6	46.1	23.1	4.3	6.3
		Range	54.0-89.0	4.1- 4.9	167.4 - 197.7	34.6-36.4	5.2-5.8	9.8-12.5	28.9-31.7	45.3-46.8	22.1-24.5	4.1-4.5	5.4-6.7
	F_2	Mean	74.7	3.9	193.9	30.7	4.7	11.3	32.2	47.3	24.9	4.1	5.7
		Range	34.0-121.0	2.5-5.1	95.1-332.0	24.7-36.5	4.0-5.8	8.7-13.4	28.1-38.3	46.5-47.7	20.1-29.8	2.7-4.7	4.7-6.9
		PCV	21	13.5	66.3	7.8	7	8.2	10.3	0.8	12.2	12.6	19.8
		GCV	16.3	11.6	65.9	7.6	6.1	6.6	10.2	0.5	11.6	10.1	19.6
		h2	60.5	73.5	98.5	94.7	76.4	65.7	97.5	40.1	90.5	64.5	97.9
		GA (%)	6.6	28.3	9.6	9.9	19.3	11.5	11.4	1.1	13	23.4	36.5
	BC_1F_1	Mean	58	3.8	203	31.8	5	10.7	35.1	46.5	27.2	3.5	5.6
		Range	41.0-125.0	2.3-4.5	114.0-326.9	27.8-34.5	4.3-5.7	8.0-12.9	30.1-38.7	42.7-46.9	21.6-32.7	2.5-4.7	4.6-6.7
		PCV	41.7	16.3	43.9	8.4	16.4	18.1	4.6	4.9	8.1	16.1	25.7
		GCV	41.5	15.6	43.4	8	15.9	17.5	4.5	4.7	8	15.8	25.6
		h2	99	92.3	97.8	91.3	94	93.3	96.8	95.5	98.7	97.1	99
		GA (%)	17.3	39.5	10.8	9.7	35.2	25.1	7.2	6.2	19.3	43	43.6
2011 (S)	CG 45SB (P_1)	Mean	54	2.9	121.3	25.5	5.2	11.7	39.8	45.6	33.2	2.8	4.7
		Range	41.0-73.0	2.5-3.2	103.4-143.6	24.5-27.6	4.8-5.9	11.4-12.8	38.6-41.2	44.7-46.1	32.6-34.6	2.5-3.2	4.3-5.1
	CG 64 (P)	Mean	78.5	4.18	229.18	35.85	5.4	9.88	30.5	46.25	24.5	4.3	5.3
		Range	56.0-86.0	3.7-4.5	211.1- 245.8	33.4-36.5	4.9-5.9	8.7-10.5	29.1-31.2	45.6-46.8	23.1-25.2	3.9-4.6	4.5-5.6
	BC_1F_2	Mean	61.5	3.58	228.44	31.59	4.68	9.99	33.7	45.37	28	3.6	5.2
		Range	36.0- 78.0	2.7-4.2	145.6-258.9	28.9-32.4	4.2-5.9	8.5-10.8	28.9-35.4	44.8-45.9	26.5-31.0	2.7-4.7	4.7-6.1
		PCV	44.3	37.8	61.2	13	19	15.9	5.6	4.5	8.5	15.7	36.1
		GCV	41.9	37.7	59.5	12.8	14.7	15.4	5.1	4.3	8.2	15.3	36
2011 (S)	BC_1F_2	h^2	89.4	99.5	94.4	76.7	59.5	94.1	82.6	93.9	94.8	94.8	99.2
		GA	17.1	66.6	13.4	12.8	24.7	24.4	6.9	6.1	11.6	40.7	54.1
2011 (W)	CG45SB (P_1)	Mean	42	2.9	87.2	26.5	4.5	12.1	39.8	46.3	32.5	2.9	4.5
		Range	35.0-56.0	2.7-3.3	56.7-102.3	24.7-27.1	4.3-4.7	11.1-13.4	38.6-40.3	45.8-46.9	30.9-33.4	2.5-3.2	4.1-4.8
	CG64(P_2)	Mean	76.3	4.1	180.1	35.6	5.2	9.2	30.7	46.3	24.3	4.3	4.9
		Range	56.0-87.0	3.8-4.6	162.7-210.3	33.4-36.5	4.7-5.9	8.7-10.3	28.7-31.4	46.2-47.5	23.4-25.6	3.9-4.5	4.7-5.5
	BC_1F_3	Mean	42	3.91	126.7	31.54	4.54	9.4	30.3	46.31	30.2	4	4.3
		Range	36.0-77.0	2.8-4.3	98.0-213.1	27.6- 33.7	4.0-5.2	8.6-10.7	28.7-33.2	45.0-46.8	27.8-33.4	2.7-4.6	4.1-4.6
		PCV	39.2	19.7	46.7	15.6	15.3	15.4	6	2.1	9.9	21.9	15.3
		GCV	38.3	18.8	44.6	15	15.2	11.2	5.8	1.8	9.7	21.8	14.7
		h2	95.5	91.1	81.5	77.7	80.3	52.6	93	74	95.9	98.7	92.1
		GA (%)	29	48.9	23.8	16.8	28.6	14.2	8.5	3.3	11.3	47.4	36
2012 (S)	CG45SB(P_1)	Mean	51	2.9	112.3	26.5	4.2	12.1	39.7	44.7	32.6	3	4.5
		Range	42.0-74.0	2.5-3.2	93.4-123.4	25.5-27.6	4.1-4.3	11.6-13.4	38.3-40.1	44.0-45.1	30.9-34.1	2.6-4.5	4.2-4..7
	CG64(P_2)	Mean	74.8	4.1	215.8	35.9	5.2	9.9	31	46.3	24.5	4.2	5.3
		Range	63.0-81.0	3.5-4.7	176.5-276.3	33.6-36.5	4.6-5.7	8.9-12.3	28.9-33.2	45.4-46.9	23.4-25.6	3.9-4.5	5.4-5.7

Table 1 contd...

Table 1 contd...

	BC_1F_4	Mean	79.3	3.12	173.92	34.37	4.45	9.53	29.8	46.82	28.9	4.4	5.1
		Range	45.0-91.0	2.6-3.7	154.3-167.6	30.3-36.5	4.1-5.4	9.3-11.7	28.4-31.4	45.3-46.9	27.9-32.5	4.1-4.7	4.5-6.1
		PCV	30.6	19.97	38.64	7.88	14.2	16.45	6.1	2.08	6.5	20.3	15.9
		GCV	30.5	19.2	35.4	7.55	14.1	15.16	5.9	1.78	6.3	19	12.4
		h2	76.8	92.48	91.5	91.8	67.8	84.95	94	73.56	93.9	87.9	61.1
		GA (%)	22	48.2	22.04	9.05	23.14	24.3	8.9	3.19	14.2	38.8	22.3
2012 (W)	CG45SB(P_1)	Mean	37	2.6	156.7	26.7	4.3	11.6	39.2	45.6	33.5	2.7	4.7
		Range	34.0-43.0	2.4-2.9	123.4-176.8	24.3-27.8	4.1-4.5	11.2-12.5	38.7-40.1	45.2-46.2	32.4-35.4	2.4-2.9	4.4-5.1
	CG64(P_2)	Mean	92.8	4.1	265.66	34.91	4.76	10.94	29.6	45	24.4	4.3	5.2
		Range	89.0-103.0	3.4-4.6	234.5-278.9	33.6-36.5	4.4-4.9	9.4-11.5	28.4-30.9	44.6-45.8	22.1-25.4	4.2-4.7	4.8-5.4
	BC_1F_5	Mean	75.7	4.05	225.67	34.17	4.22	10.11	28.7	46.5	29.4	4.3	5
		Range	45.0-89.0	3.5-4.5	176.8-319.0	33.4-36.5	4.0-4.7	8.9-11.7	27.6-30.9	46.0-46.9	28.7-33.4	4.1-4.9	4.1-5.7
		PCV	24.3	15.34	22.85	7.03	16.09	14.55	5.6	2.34	7.2	13.1	10.6
		GCV	23.2	13.07	22.3	6.43	15.59	14.54	5.5	2.11	6.6	12.9	10.2
		h2	86.3	72.56	75.26	83.77	93.92	99.78	98.4	87.9	83.5	97.8	86.5
		GA (%)	26.7	33.53	33.22	7.83	37.79	27.53	8.9	4.62	26.9	35.1	12.5
2013 (S)	CG45SB(P_1)	Mean	45	2.8	167.8	26.5	4.7	11.3	40.2	45.6	32.4	2.8	4.5
		Range	32.0-57.0	2.5-3.5	145.6-178.9	24.5-27.8	4.1-5.2	10.2-12.3	38.7-41.2	44.2-45.8	30.9-33.7	2.6-3.1	4.4-5.1
	CG64(P_2)	Mean	80	3.78	177.75	35.74	5.22	10.28	29.8	45.9	23.2	4.6	4.6
		Range	46.0-93.0	3.5-4.4	156.7-186.7	34.1-36.5	4.3-5.6	9.6-11.2	28.4-31.5	45.3-46.1	22.1-24.5	4.1-4.7	4.1-5.2
	BC_1F_6	Mean	69.9	3.12	182.89	32.57	4.55	9.41	29.1	45.84	30.1	4.9	5
		Range	49.0-82.8	2.7-3.5	167.6-203.4	29.1-33.4	4.1-4.9	8.7-11.2	28.7-31.3	44.9-46.2	29.1-33.1	4.3-5.2	4.1-5.4
		PCV	21	13.48	36.34	7.84	7.03	8.19	10.3	7.9	6.7	12.6	19.8
		GCV	20.3	11.56	35.85	7.63	7.14	6.64	10.2	5	6.6	10.1	19.6
		h2	78.9	73.51	78.51	94.73	76.41	65.73	97.5	50.06	87.4	64.5	97.9
		GA (%)	36.6	28.27	29.64	9.87	29.3	11.53	11.4	4.07	23.4	23.4	36.5
2013 (W)	CG45SB (P_1)	Mean	47	2.7	153	26.7	4.6	11.5	38.7	45.7	33.1	2.9	5.4
		Range	36.0-67.0	2.5-3.6	123.4-189.7	25.6-27.6	4.1-5.2	11.2-12.3	37.4-39.6	45.3-46.2	32.1-34.2	2.7-3.1	5.3-5.8
	CG64(P_2)	Mean	74.3	3.76	195.27	35.67	5.37	10.86	30.2	46.57	23.2	4.3	5.9
		Range	54.0-82.0	3.4-4.5	145.6-207.8	34.2-36.1	4.9-5.6	10.5-11.4	29.9-31.4	45.6-47.9	22.1-24.3	3.9-4.7	5.4-6.1
2013 (W)	BC_1F_7	Mean	88.3	3.44	213.68	33.32	5	10.01	28.9	45.51	30	4.9	5
		Range	73.0-92.0	3.0-4.1	166.0-254.6	31.2-34.5	4.5-5.6	9.4-11.3	27.9-31.5	44.7-46.1	29.1-34.4	4.4-5.1	4.6-5.7
		PCV	20.7	11.55	25.27	15.64	19.69	9.83	14.1	11.67	6.4	20.6	10.6
		GCV	20.6	10.14	24.92	15.26	17.73	9.33	14	11.23	6.3	18.4	10.5
		h2	87.6	77.1	87.24	77.09	63.55	90.06	83.5	54.62	76.5	63	79.7
		GA (%)	19.8	29.1	26.89	7.38	18.22	18.38	7.3	2.11	21.3	19	23.4
2014 (S)	CG45SB(P_1)	Mean	47	2.7	176.7	26.6	4.6	11.6	40.3	45.6	33.4	2.8	4.5
		Range	35.0-67.0	2.4-3.1	134.5-199.7	25.4-27.7	4.3-5.1	11.1- 12.0	39.8-41.5	44.7-45.8	31.2-35.5	2.5-3.1	4.3-4.7
	CG64(P_2)	Mean	65	4.2	190.8	35.03	5.35	10.15	29.8	46.9	23.7	4.8	6.3
		Range	43.0-78.0	3.6-4.7	167.0-203.7	34.5-36.7	4.3-5.6	9.9-10.7	28.7-31.6	46.2-47.5	22.3-24.3	4.5-4.9	5.6-6.4
	BC_1F_8	Mean	66.9	3.22	183.6	32.47	5.09	10.55	29.4	46.38	30.4	4.9	5.1
		Range	56.0-87.0	2.9-3.5	144.5-223.4	30.8-33.6	4.4-5.4	9.9-10.9	28.5-31.3	45.8-46.5	28.9-33.1	4.7-5.1	4.5-5.9
		PCV	18.9	12.1	15.4	17.9	17.3	19.8	9.1	14.3	6.1	17.1	8.2
		GCV	18.4	11.7	15.1	17.8	17.1	19.6	9	14.3	6	16	8.2
		h2	78.5	68.8	65.3	99	87.6	76.9	98.4	99.3	79.4	92.1	67.8
		GA (%)	23.4	24.4	28.9	9.5	32.5	23.4	8.2	4.1	29	24.9	24.9

Table 2.Estimates of variability, heritability and genetic advance as per cent of mean in modified backcross population-I

Season	Particulars		Bolls / Plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2011 (S)	CG45SB (P_1)	Mean	56	3.1	121.5	26.5	4.5	12.3	39.5	43.5	33.4	2.9	4.5
		Range	47.0 - 62.0	2.9-3.1	110.5-133.2	24.2-27.3	4.1- 4.6	12.0-12.5	39.0-40.1	43.2-43.7	32.5-34.1	2.6-3.1	4.2-4.7
	CG67 (P2)	Mean	76	4.3	228.1	31	4.6	10.3	36.1	43.7	25.3	3.4	4.8
		Range	71.0 -83.0	4.1-4.9	212.4 -234.3	30.12-32.10	4.4 -5.1	9.8-10.9	35.6-36.7	43.2-43.8	24.9-25.6	3.1-3.9	4.4-5.1
	MBC1F1	Mean	88.5	4.4	333.7	31.1	4.9	10.7	36.3	43.7	24.4	3.2	4.7
		Range	64.0 -115.0	3.5-5.6	178.3 - 412.3	29.3 -34.5	3.9 -5.7	9.7-13.1	34.1-38.3	43.1-43.8	24.3-31.5	3.1-4.2	4.6-5.9
		PCV	28.9	14.5	33.7	23.4	24.9	25.3	4.6	26.2	35.8	14.3	13
		GCV	28.8	13.7	33.4	21.8	24	23.4	4.2	26.3	35.6	13.4	11.6
		h2	85.7	76.5	98.8	78.7	65.7	67.9	78.2	63.1	78.3	93.4	91.1
		GA (%)	19.2	19.9	25.6	6.2	29.2	12.9	10.1	3.5	25.3	24	19.6
2011 (W)	CG45SB	Mean	64	2.6	180.2	25.7	4.6	12.4	40.1	44	34.2	2.7	4.9
	(P1)	Range	45.0 - 67.0	2.8-3.4	125.0 -198.0	27.5	4.2-5.3	11.9-13.1	38.9-40.2	44-44.8	33.5-35.7	2.5-3.1	4.2-5.6
	CG67	Mean	83	4.1	236.2	32.2	5.1	10.8	36	44.3	25.4	3.1	5.7
	(P2)	Range	56.0 -106.0	3.9-5.1	198.0 -332.2	31.6 -33.4	5.1-5.6	10.1-11.3	35.1-36.5	44.1-44.7	24.6-26.1	3.1-3.6	4.7-6.1
	MBC1F2	Mean	92.4	3.7	244	32.6	4.9	10	33.4	44.8	26.9	3.4	4.9
		Range	43.0-142.0	2.6-4.7	78.0 - 345.5	26.7-32.4	4.1-5.4	8.9-12.3	31.4-38.1	44.1-45.2	24.1- 29.6	2.8-4.1	4.1-5.5
		PCV	35.6	24.6	45.3	34.3	57.5	35.5	24.4	32.1	23	19.2	12.3
		GCV	34.1	24.3	43.4	32.1	55.4	32.5	23.8	31.6	22.7	19.1	10.1
		h2	96.2	98.6	97.6	67.9	88	76.6	90	78.4	91.5	99.6	65.3
		GA (%)	21.1	21.3	34.6	4.8	23.8	13.6	10.1	13.7	26	14.4	18.2
2012 (S)	CG45SB	Mean	57	3.2	150	26.9	4.5	12.8	39.1	44.1	32.4	3.1	4.4
	(P1)	Range	39.0-65.0	2.5-3.5	93-201	24.9 -27.8	3.9-5.0	11.2-13.4	38.7-40.8	44.2-45.4	31.2-34.2	2.6-3.7	4.2-4.8
	CG67	Mean	97.8	4.3	255.7	32.8	4.6	9.2	34.2	43.3	25	3.2	4.7
	(P2)	Range	87.0 -106.0	4.1-4.8	200.1-306.2	31.3 -34.5	4.1-5.1	8.3-10.7	34.1-35.2	43.1-44.0	24.3-26.1	2.9-3.9	4.3-5.7
	MBC1F3	Mean	101.9	3.6	258.1	31.6	4.2	9.1	34.6	44	27.9	3.6	4.4
		Range	87.0 -130.0	3.0-4.7	120.0 - 285.5	29.7 -33.2	3.9-5.9	8.5-10.3	32.4-35.1	43.1-44.2	26.1- 30.1	2.9-3.9	4.2-4.9
		PCV	15.9	58.8	32.3	17.7	32.8	36.2	17.4	15.1	18.4	45.9	50.8
		GCV	15	58.5	30.9	17.6	31.1	34.4	17.3	15	18.2	45.8	49.1
		h2	89.6	99.4	91.5	79	98.7	87.6	56.3	82.3	85.3	99.8	76.6
		GA (%)	22.8	27.3	26.7	5	29.1	21.8	11.9	9.4	36.3	17.8	21.3

Table 2 contd...

Table 2 contd...

2012 (W)	CG45SB	Mean	59	2.9	142.3	26.8	4.6	11.9	40.2	44.6	32.8	3.1	4.7
	(P1)	Range	45.0 - 68.0	2.5-3.2	98-167	25.2-27.1	4.4-5.1	10.8-12.3	39.5-41.2	44.3-45.2	31.3-33.7	2.9-3.2	4.5-5.1
	CG67	Mean	88.8	4.5	281.7	31.7	4.8	10.5	35.4	44.8	25.8	3.8	5.7
	(P2)	Range	76-97	4.1-4.9	267.2 - 298.0	30.4 -32.5	4.1-4.9	10.2-10.7	34.5-35.6	44.1-45.8	24.3-25.8	3.9-4.2	5.3-5.9
	MBC1F4	Mean	97	4	272.3	30.2	4.6	11.4	33.5	43.3	28.7	3.5	5.1
		Range	86.0 -114.2	3.5-4.2	201.0 - 295.5	28.7-32.2	4.3-5.1	10.9-11.9	32.1-34.6	43.0-43.7	27.6- 29.1	2.9-3.9	4.2-4.9
		PCV	12.4	19.2	27.2	8.9	18.7	23.3	11.2	8.9	14.4	16.8	17.5
		GCV	12	18.7	27	8.8	18.1	21.5	10.1	8.5	14.3	10.9	16.9
		h2	93.6	97.6	90.7	67.9	96.6	96.1	54.9	75.6	97.4	64.8	96.4
		GA (%)	20.7	20.6	22.3	4.7	20.5	9.6	4.4	5.4	33.8	25.5	19
2013 (S)	CG45SB	Mean	67	3.2	171.3	27.1	5	12.3	38.9	44.1	32.9	3.1	4.7
	(P1)		56.0-78.0	2.9-3.7	134.4 -198.3	25.7-28.3	4.6-5.4	11.5-12.7	37.6-39.7	43.5-44.7	31.5-33.5	2.6-3.6	4.3-5.1
	CG67	Mean	89	4.4	372.8	31.3	5.2	11.3	34.9	43.4	25.8	3.5	4.8
	(P2)		75-97	4.0-4.7	342.7-397.5	30.9 -32.2	4.7-5.5	10.9-11.9	33.4-35.1	43.2-43.7	25.2-26.2	3.1-3.7	4.3-5.1
	MBC1F5	Mean	92.1	4.1	362.9	31.3	4.7	10.4	32.6	45.4	29.3	3.6	4.5
		Range	72.0-109.0	3.9-4.7	332.6-398.7	29.6 -31.9	4.3-5.4	9.8-11.5	31.5-35.6	44.3-45.7	28.7-30.5	3.4-4.1	4.6-5.1
		PCV	10.5	18.3	24.2	9.7	13.7	13.9	5.5	7.6	14.8	15.2	13
		GCV	10.7	18	23.9	9.4	12.7	12.1	5	6.3	14.3	12.2	10.5
		h2	97.6	98.4	87.7	79	92.8	86.7	89.6	82.8	88.5	80.5	65.3
		GA(%)	23.9	18.3	30.1	5.5	19.9	14.6	5.1	5.4	25.1	26.4	19.8
2013 (W)	CG45SB	Mean	45	2.9	94.3	24.8	4.3	11.9	38.7	44	31.9	2.9	4.9
	(P1)	Range	37.0 - 49.0	2.5-3.1	57.3 -112.3	24.1-25.4	4.1-4.6	11.4-12.5	37.8-39.8	43.8-44.2	30.1-33.6	2.6-3.7	4.5-5.3
	CG67	Mean	51.3	4.3	134.3	32.1	4.9	11	35.2	44.5	26	3.6	5
	(P2)	Range	45.0 - 67.0	3.9-4.8	121.3-156.3	31.1 -33.2	4.1-5.3	10.8-11.3	34.5-36.1	43.8-45.1	25.3-26.8	3.4-4.1	4.6-5.7
	MBC1F6	Mean	54.6	4.1	154.9	31	5	11.2	33.4	44.9	29.3	4.2	4.5
		Range	43.0 -71.0	4.2-4.7	127.3-178.9	28.9 -32.3	4.5-5.7	10.8-11.7	32.1-34.5	44.1-45.3	28.9-31.3	3.9-4.5	4.6-5.1
		PCV	7.4	14.8	12.7	8.1	12	11.1	5.7	6.7	15.4	13.2	12.8
		GCV	7.1	12.9	11.4	7.9	10.3	10.4	5.6	5.5	15.1	12.2	10.3
		h2	96.3	87.6	88	79	85.8	94	98.5	85.6	93.1	92.7	69.2
		GA (%)	25.6	23.9	26.6	4.6	20.6	11.2	3.5	7.6	35	20.7	16

Table 3. Estimates of variability, heritability and genetic advance as per cent of mean in modified backcross population-II

Season	Particulars		Bolls / plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2011 (S)	CG45SB (P1)	Mean	78	3.2	174.3	26.4	5.1	12.4	40.3	44	34.6	3.1	4.2
		Range	45 .0 - 87.0	2.9-3.1	154.3 -89.7	24.3-27.6	4.7-5.9	11.9-13.2	39.8-41.2	43.5-44.7	32.6-35.3	2.9-3.2	4.0-4.3
	CG92 (P2)	Mean	89	4.37	271.69	34.72	5.73	10.3	34.5	44.67	26.07	3.27	4.33
		Range	76.0 - 97.0	3.9-5.7	213.1-301.3	33.1-34.76	5.1-6.1	8.7-11.5	33.5-34.7	44.2-44.89	24.7-27.1	3.1-3.4	4.5-4.9
	MBC1F1	Mean	75.53	4.79	253.32	32.5	5.37	11.22	34.93	44.85	24.07	3.43	4.33
		Range	43.0-121.0	3.4-6.1	178.1-345.2	27.3-35.1	4.4-5.6	9.8-13.4	31.4-37.8	43.4-44.5	24.7-31.2	2.9-3.7	4.2-5.1
		PCV	34.55	17.06	28.88	6.31	13.94	13.81	15.17	1.77	34.5	13.71	16.13
		GCV	34.22	16.5	28.87	6.3	10.49	13.72	15.02	1.22	36.5	12.96	9.05
		h2	68	86.7	78.9	67.8	75.25	99.37	87.05	68.68	78.59	94.58	56.13
		GA (%)	19.5	18.97	32.45	12.1	20.27	7.59	13.78	2.4	16.78	22.19	20.31
2011 (W)	CG45SB (P1)	Mean	69.45	2.9	167.2	25.7	4.5	11.9	38.9	45	32.4	2.9	4.33
		Range	54.0-76.0	2.3-3.9	154.0-186.7	24.3-26.8	4.1-5.2	11.0-12.3	37.8-39.6	44.5-46.1	31.3-34.2	2.5-3.5	4.1-4.6
	CG92(P2)	Mean	84.67	4.77	282.66	34.89	6.23	11.73	34.73	45.33	24.93	3.37	4.63
		Range	67.0-92.0	4.1-5.3	234.0-345.6	33.31-35.61	5.4-7.1	10.9-12.4	32.8-35.4	44.6-46.7	24.3-25.7	3.1-3.7	4.4- 5.1
	MBC1F2	Mean	73.04	3.8	258.1	33.3	5.1	10.1	33.36	45.07	27.13	3.19	4.5
		Range	32.0-136.0	2.5-4.6	115.4.1-413.2	26.41-34.56	4.7-6.3	8.7-12.1	29.1-35.6	44.5-45.9	24.3-32.3	2.7-3.8	4.3-4.9
		PCV	19.35	23.16	30.99	9.15	20.58	17.69	13.82	2.19	23.4	21.68	16.3
		GCV	19.07	21.72	29.53	8.91	18.48	16.65	13.62	1.78	22.7	19.69	14.52
		h2	98.52	93.77	86.78	57.38	89.79	94.14	94.83	81.19	79.6	80.84	76.81
		GA (%)	23.41	34.56	24.56	13.67	23.45	8.7	9.24	1.27	20.45	21.01	11.2
2012 (S)	CG45SB (P1)	Mean	54	2.8	135.8	25.6	4.5	12.1	40.4	43.45	31.9	3.1	4.5
		Range	45.0-67.0	2.4-3.1	124.5-145.6	24.34-26.32	4.3-4.8	11.2-12.7	38.9-41.5	43.0-43.9	30.1-32.7	2.9-3.4	4.3-5.2
	CG92 (P2)	Mean	94.67	3.77	249.5	32.89	5.17	9.67	33.1	44.1	25	3.5	4.67
		Range	83.0-108.0	3.5-4.4	223.4-262.1	31.32-34.21	4.1-6.3	8.7-10.2	32.7-34.5	42.5-47.6	24.6-26.4	3.1-3.7	4.3-5.1
	MBC1F3	Mean	97.98	4.2	261.95	33.07	4.76	9.75	32.63	43.43	27.14	3.59	4.57
		Range	67.0-123.0	3.7-4.8	178.0-314.5	31.57-34.34	4.3-5.4	9.1 -12.1	29.6-34.7	43.2-43.6	26.8-34.2	2.9-3.7	4.2-5.2
		PCV	20	17.43	27.79	5.67	11.88	12.96	10.45	1.42	13.56	15.95	13.79
		GCV	19.83	16.96	27.6	5.23	11.82	11.01	10.32	0.57	12.5	15.7	12.53
		h2	78.98	97.3	77.45	71.37	67.89	84.98	83.22	40.1	73.1	98.46	80.1
		GA (%)	34.21	20.64	19.17	7.8	20.34	14.66	12.47	1.41	19.67	17.89	23.73
2012 (W)	CG45SB (P1)	Mean	62	3.2	156.7	25.4	4.5	11.7	39.8	44.5	32.3	3.1	4.7
		Range	55.0-71.0	2.7-3.8	134.5-176.4	24.45-27.65	4.2-4.7	11.1-12.2	38.6-41.2	43.6-45.7	31.4-34.6	2.9-3.3	4.3-4.9
	CG92 (P2)	Mean	87.67	4.9	300.79	34.57	6	11.43	34.67	44.7	26.33	3.3	5.1
		Range	76.0-93.0	3.9-5.4	267.8-385.6	32.56-35.2	5.3-6.5	11.4-12.1	34.2-35.6	43.4-45.6	25.3-27.1	2.9-3.5	4.7-5.6

Table 3 contd...

Table 3 contd...

	MBC1F4	Mean	93.83	4.6	258.64	32.25	5.05	10.74	32.12	44.05	27.6	3.72	4.9
		Range	76.0-115.0	3.8-5.4	214.5-277.8	30.2-34.56	4.6-6.7	9.7-11.3	29.8-34.2	43.2-45.3	26.4-31.2	3.2-3.9	4.6-5.4
		PCV	16.24	13.84	25.16	8.61	12.7	13.45	5.16	2.26	19.41	15.04	9.66
		GCV	15.3	13.29	23.63	8.39	12.19	13.31	4.58	1.84	18.22	13.25	8.29
		h2	94.16	96.91	93.94	78.6	96.76	98.96	88.76	81.38	73	88.09	85.8
		GA (%)	26.17	21.13	24.56	4.96	17.66	8.66	4.98	2.89	21.34	25.12	17.05
2013 (S)	CG45SB (P1)	Mean	75	2.9	167.8	26.3	4.5	12.6	40.3	45.3	34.5	2.9	4.5
			64.0-86.0	2.7-3.5	134.5-178.9	24.56-27.89	4.1-4.6	11.2-13.2	38.7-42.3	44.2-45.7	32.78-35.67	2.6-3.2	4.2-4.8
	CG92 (P2)	Mean	76.75	4.28	229.6	35.14	6.28	11.68	34.2	45.5	26.1	3.4	4.75
			68.0-83.0	4.1-5.3	214.5-254.6	32.34-36.71	5.4-7.1	11.2-12.7	33.2-36.5	44.3-46.1	25.4-27.8	3.0-3.7	4.2-5.4
	MBC1F5	Mean	73.65	4.6	219.69	33.68	5.57	10.93	30.92	44.51	29.15	4.07	4.49
		Range	67.0-82.0	3.9-5.2	197.1-236.7	32.1-34.56	4.7-6.8	9.2-12.3	28.7-33.5	43.4-46.1	28.7-32.4	3.6-4.4	4.3-5.4
		PCV	15.42	12.34	15.64	7.05	15.6	13.55	6.27	2.51	15.77	19.51	11.59
		GCV	15.12	11.97	14.98	6.98	14.94	12.71	6.11	2.18	15.63	18.78	5.46
		h2	67.89	89.76	67.89	89.02	95.77	93.83	97.57	86.94	87.73	96.23	47.08
		GA(%)	19.85	23.45	21.34	3.48	21.23	12.66	4.23	2.93	24.12	22.63	14.02
2013 (W)	CG45SB (P1)	Mean	58	3.2	172.2	25.4	5.3	12.1	38.7	44.4	33.2	2.9	4.7
		Range	49.0-64.0	2.8-3.4	145.3-189.9	23.45-26.56	4.7-5.8	11.7-12.6	37.8-39.9	43.7-44.9	32.7-35.7	2.5-3.1	4.2-5.5
	CG92 (P2)	Mean	76.75	4.23	226.87	35.14	6.28	11.78	34.23	44.5	25.9	3.4	4.85
		Range	69.0-89.0	3.8-5.4	212.0-256.3	34.5-35.78	5.5-7.3	10.9-12.4	33.7-35.6	43.7-45.1	24.9-27.6	2.9-3.8	4.3-5.3
	MBC1F6	Mean	71.52	4.67	252.27	33.12	5.8	11.7	31.13	44.06	31.34	4.1	4.5
		Range	43.0-83.0	4.1-5.2	214.6-275.7	31.23-34.56	5.1-6.9	10.7-12.9	30.9-33.5	44.2-45.3	29.7-33.2	3.5-4.7	4.3-5.2
		PCV	10.34	9.78	12.34	6.47	12.7	12.72	8.34	6.65	11.21	10.19	14.37
		GCV	9.76	8.56	12.17	6.39	11.95	12.2	8.22	6.53	11..17	9.19	12.11
		h2	79.84	67.89	89.76	98.8	94.06	95.95	98.49	98.21	89.44	90.16	70.38
		GA (%)	23.41	19.63	34.56	3.53	16.71	10.94	4.37	3.34	23.4	17.62	20.93

fibre strength, the parent P_1 recorded higher mean values.

All the derived back cross progenies showed long staple length (28.5 to 31.3), while the modified back cross progenies expressed long and extra-long 2.5 per cent staple length. All the progenies recorded high fibre strength than the parent P_2 (more than 28 g/tex).Micronaire mean values showed, the back cross progenies was coarse when compared with P_2 and modified back cross progenies was having ideal micronaire (3.5 to 4.7) value. The derived population was on par P_2 for the traits uniformity ratio and elongation per cent.

Variability : In early generation of backcross population I, high PCV, GCV were recorded in boll number, seed cotton yield and elongation ratio. While the early generations of modified back cross I and II populations, the traits namely, bolls/plant, seed cotton yield, lint index, seed index, fibre strength and uniformity ratio showed high PCV, GCV indicating greater variability and scope for improvement of the character. Similar findings were reported byRanganatha *et al.,* (2013), Rao and Gopinath (2013), Dhivya *et al.,* (2014) and Khan *et al.,* (2015).

Moderate and low PCV, GCV were recorded in ginning per cent, boll weight, lint index, seed index, 2.5 per cent span length and micronaire in early generations of back cross population I. In case of modified back cross populations low PCV, GCV were recorded for boll weight, 2.5 per cent span length, micronaire and elongation per cent. Similar results were earlier reported by Rao and Gopinath (2013), Kusugal *et al.,* (2014), Pujer *et al.,* (2014) and Khan *et al.,* (2015).

Most of the traits exhibiting high or moderate phenotypic and genotypic coefficient of variation in early generations whereas in later generations it goes down to moderate or low. In all the generations the phenotypic variation was higher than genotypic variation and showed the presence of environmental influence over the traits. It clearly indicates that the majority of characters showed narrow range of variation in later generation because of single plant selection.

Heritability and GA as per cent of mean: High heritability and high genetic advance were observed in all the traits in the advanced generations of all the three crosses. This indicates the preponderance of additive gene action in the inheritance of these traits and offers the scope for improvement through simple selection procedures. Similar results were earlier reported by Rao and Gopinath (2013), Dhivya *et al.*, (2014), Pujer *et al.*, (2014) and Khan *et al.*, (2015).

High heritability coupled with moderate or low genetic advance were observed in ginning per cent, 2.5 per cent span length and uniformity ratio indicating the role of additive and non-additive gene action in the inheritance of this trait. This can be improved through cyclic hybridization, diallel selective mating and biparental mating. The results are in agreement with the research findings of Pujer *et al.*, (2014) and Khan *et al.*, (2015).

In the present study, long staple (28.5-31.3 mm) with high fibre strength (28.9-33.1 g/tex) line with *hirsutum* background were obtained in the back cross I populations. Similarly in modified back cross I, long and extra-long staple (32.1-34.5) lines with high fibre strength (28.9-31.3) and in modified backcross II, long and extra-long staple (30.9-33.5) lines with high fibre strength (29.7-33.2) with recurrent plant background were obtained. The fibre quality parameters were assessed by SITRA and CIRCOT fibre testing labs in ICC mode and confirms the findings of the present study.

REFERENCE

Basbag S., and Gencer O., 2004. Investigations on the heritability of seed cotton yield, yield components and technological characters in cotton (*G. hirsutum* L.), *Pak. J. Biol. Sci.,* **7 :** 1390

Burton G.W., and Devane E.M., 1953. Estimating heritability in fall fescue (*Festecd cirunclindcede*) from replicated clonal material, *Agron. J.,* **45 :** 478-81

Dhivya, R., P. Amala Balu, R. Pushpa and D. Kavithamani 2014. Variability, heritability and genetic advance in upland cotton (*Gossypium hirsutum* L.). *African J. Plant Sci.* **8 :** 1-5.

Khan, F. U. Z., S. U. Rehman, M. A. Abid, W. Malik, C. M. Hanif, M. Bilal, G. Qanmber, A. Latif, J. Ashraf and U. Farhan . 2015. Exploitation of Germplasm for Plant Yield Improvement in Cotton (*Gossypium hirsutum* L.) *J Green Physiol Genet Genom* **1** : 1-10.

Kohel, R.J. 1999. Cotton germplasm resources and the potential for improved fibre production and quality.In: Cotton fibres. A.S. Basra (eds.), The Haworth press, New York. Pp167–182.

Kusugal, A., S. S. Patil, K. J. Pranesh, S. Rajeev and H. K. Reddy. 2014. Improving genetic base of Gossypium barbadense for developing potential inter specific hybrids. *Electronic J. Plant Breeding,* **5 :** 594-601

Pujer, S., S.S. Siwach, JagadeeshDeshmukh, R.S. Sangwan and O. Sangwan. 2014. Genetic variability, correlation and path analysis in upland cotton (*Gossypium hirsutum* L.). *Electronic J. Plant Breeding,* **5 :** 284-89

Ranganatha, H.M., Shreekanth, S.P., Manjula, S.M and Kumar, B.N.A. 2013. Genetic variability studies in segregating generation of upland cotton (*Gossypium hirsutum* L.). Molecular *Plant Breeding.* **4 :** 84-88.

Robinson H.E., Comstock R.E. and Harvay P.H., 1951, Genotypic and phenotypic correlations in corn and their implications in selection, *Agron. J.,* **43 :** 282-87

Rao, P.J.M and Gopinath, M. 2013. Variability and association studies for yield and yield components in upland cotton (Gossypium hirsutum L.) under chalkasoils.*Electronic J. Plant Breeding.* **4 :** 1093-96.

Singh R.K., and Chaudhary B.D., 1977, *Biometrical Methods in QuantitativeGenetic Analysis,* Kalyani Publishers New Delhi

Soregaon, C.D., R.P. Veereshgowda, I.S. Katageri and B.M. Khadi. 2007. Introgression of fibre traits of *Gossypium barbadense* L. into *Gossypium hirsutum* L. *Indian J. Genet.* **67 :** 56–61.

Ulloa, M., Hutmacher, R.B., Davis, R.M., Wright, S.D., Percy, R and Marsh, B. 2006. Breeding for Fusarium wilt race 4 resistances in cotton under field and greenhouse conditions. *Jour. Cotton Sci.* **10 :** 114-27.

Zhang, H.B., Y. Li, B. Wang and P.W. Chee. 2008. Recent Advances in Cotton Genomics. Intl. *J. Plant Genomics,* 1–20.

Genetic analysis in cotton (*Gossypium hirsutum* L.) for mechanical harvesting characters

P. KARTHIKEYAN, K. RAMYA, N. KANNAN, R. SELVAKUMAR, C. R. ANANDAKUMAR
Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore
E-mail : kannan@rasiseeds.com

ABSTRACT : The present investigation on cotton (*Gossypium hirsutum* L.) was undertaken to study the genetics of plant ideotype characters and to develop superior cotton hybrids suitable for mechanical harvesting. Twenty one crosses obtained by crossing 7 × 3 genotypes in line × tester fashion and their parents were evaluated for 11 biometric traits. Based on mechanical harvesting viewpoint, the desirable features such as earliness, short and compact plant type, absence of monopodial branch, short sympodial branch, synchronous boll bursting, bigger and high weighing bolls, high single plant yield and high ginning per cent with desired fibre quality characters were considered as suitable for developing ideotypes. The lines namely L316, L186, L317, L64 and the testers namely T308, T293 showed significant *per se* performanceand *gca* effects. The hybrids *viz.,* L316 × T308, L64 × T293 and L95 × T240 recorded significant overall performance, considering the suitability for mechanical harvesting, *per se* performance and*sca* effects. These selected hybrids further need to be evaluated for their efficacy to defoliant and plant growth regulator applications.

Cotton is one of the important commercial crops and it serves as a main source of raw material to the textile industry in India. It has the distinction of having the largest area under cotton cultivation in the world with 12.2 million hectares and constituting about 25 per cent of the world area under cotton cultivation. In India almost the entire cotton is harvested through hand-picking by human labor spending about 0.9 man-hr/kg of cotton and costing almost 10 times more of irrigation and two times the weeding costs (Muthumilselvan *et al.*, 2007). India is lagging behind many other large producers of cotton in mechanization of harvesting. In USA, machines are used to harvest the entire cotton crop, whereas in some regions of China, it is predicted that by 2020, about 60 per cent of cotton will be mechanically picked (Business line, 2012). It is expected that the country will soon have to mechanize its cotton harvesting operations as it is facing labor shortages and rising farm wages.

There are various types and designs of cotton harvesting machines available in the world. In advanced countries like USA, Australia, Brazil and Russia, cotton picking is carried out mechanically by cotton pickers (most commonly used machines) and cotton strippers. These harvesters are designed to suit for the particular plant types and planting system, established in those countries. For Indian researchers, manufacturers and farmers it is a very difficult task to design and select a cotton harvester due to non-uniformity in plant stature, staggered blooming characteristics (Prasad *et al.,* 2004) and different planting systems followed in different regions of the country.

With regard to the plant stature, cotton genotypes that are presently cultivated in India have an inherent defect in the form of large bushy plant type and asynchronous boll maturity, which makes it impossible to use mechanical harvesters in cotton. In order to successfully employ cotton harvesters, high yielding varieties or hybrids with short stature, zero monopodial, less sympodial, early maturing, synchronous boll opening need to be developed and tested under high density planting system. Literature search indicates that, the research on breeding for crop ideotypes suitable for mechanical harvesting are very limited in cotton. This warrants immediate attention of researchers for the development of suitable genotypes for mechanical harvesting through ideotype breeding.

Cotton improvement programmes primarily lay emphasis on development of hybrids, which have contributed in improving the productivity of cotton (Christopher *et al.,* 2003). In heterosis breeding programme, the selection of parents or inbreds based on their morphological diversity with good combining ability is very important in producing superior hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents or inbreds for the production of superior hybrids. The Line × Tester analysis (Kempthorne, 1957) is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability. Based on the information from Line × Tester analysis development of commercially viable hybrids is possible.

MATERIALS AND METHODS

The experimental material used in the present study comprised of 10 parents (7 lines and 3 testers) and 21 (7×3) crosses along with a check. The hybrids were derived by following the line × tester mating design. The experiment was conducted at Research Farm of Rasi Seeds, which is situated at Attur, Tamil Nadu. 21 crosses with check were raised with three replications in a randomized block design (RBD) and each cross was raised in three rows of 6 m length with the spacing of 90 × 15 cm. The parents (7 lines and 3 testers) were also raised separately in the same way of the adjacent block. Recommended agronomic practices and need based plant protection measures were followed under irrigated condition to obtain good crop stand. Data were recorded for 11 biometric traits namely days to fifty per cent flowering, days to first boll bursting, plant height, plant width, height of lower most boll, sympodial branches/plant, bolls/plant, boll weight, seed cotton yield/plant, ginning per cent and lint index.

The mean data collected from F_1s, parents and checks were subjected to statistical analysis to estimate the combining ability of parents and hybrids and heterosis of hybrids using the TNAUSTAT statistical analysis software, (Tamil Nadu Agricultural University, Coimbatore).The mean data of 21 hybrids and their parents for each quantitative character were tabulated and subjected to appropriate analysis of variance separately (Panse and Sukhatme, 1964)

RESULTS AND DISCUSSION

The range of ideotype values suitable for mechanical harvesting for the plant architecture and yield traits at the spacing suitable for high density planting are define based on the literatures search and results of the present study. Analysis of variance for plant architecture traits are presented in Table 1. Analysis of variance showed significant differences among the parental genotypes for all the 11traits studied. The crosses showed significant differences for all the 11traits. The interaction between the parents and the crosses also recorded significant differences for all characters except days to fifty per cent flowering and ginning per cent.Giri *et al.*, (2006) and Subba Reddy and Nadarajan (2006) reported significant differences

Table 1. Analysis of variance for plant architecture and yield traits

Source	DF	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Replication	2	9.88	74.11	38.71	0.46	0.40	2.40	0.82	0.02	3.51	4.19	0.03
Genotypes	30	6.30**	15.87**	505.22**	346.51**	50.34**	5.02**	40.30**	1.06**	559.61**	23.04**	1.37**
Parents	9	3.20**	12.00*	833.11**	330.37**	46.21**	7.54**	15.39**	0.91**	771.4**	32.01**	1.92**
Lines	6	2.10	14.65*	1125.83**	339.52**	55.97**	10.49**	21.94**	0.49**	486.3**	37.65**	1.44**
Testers	2	4.00*	0.44	340.11**	46.33**	39.00**	0.78	3.44**	0.88**	383.8**	2.66	1.17**
Lines *V/s.* Testers	1	8.23**	19.21	62.86**	843.56**	2.06	3.36**	0.03	3.50**	3257.7**	56.89**	6.29**
Cross *V/s.* Parents	1	2.57	25.81*	2328.11**	1053.99**	4.55*	12.19**	502.27**	12.37**	2395.88**	0.10	6.97**
Error	60	1.14	4.94	6.92	3.70	0.90	0.32	0.38	0.02	4.97	3.05	0.06

Table 2. Analysis of variance for combining ability for plant architecture and yield traits

Source	DF	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Replication	2	6.49	55.44	20.06	0.02	0.49	2.02	0.62	0.04	3.86	1.64	0.05
Lines	6	6.81**	9.42	591.48**	438.88**	53.98**	2.70**	35.76**	0.97**	550.01**	30.32**	0.96**
Testers	2	23.16**	13.44	44.49**	102.78**	39.73**	5.44**	20.33**	0.37**	664.48**	0.40	2.52**
L × T	12	5.86**	21.57**	141.05**	294.09**	57.19**	3.61**	26.07**	0.40**	235.00**	18.35**	0.49**
Error	40	1.11	4.24	7.18	4.07	0.76	0.35	0.45	0.02	5.86	3.15	0.07

**– Significant at 1% level, *– Significant at 5% level

among the cotton genotypes for all the yield and yield related traits.

The analyses of variance for combining ability for the plant architecture traits are presented in Table. 2. The ANOVA sowed that mean squares due to lines were highly significant for all the traits except for the days to first boll bursting. The testers showed highly significant differences for all the traits except days to first boll bursting and ginning per cent. The interaction between L × T had significant deviation for all the 11traits of the present study. Similar findings were reported by Punitha *et al.*, (2008). The relative estimates of variances due to additive and dominance components are presented in Table 3. The dominance variance was higher than the additive variance for all the 11 biometric traits. The ratio between additive and dominance variance was less than one for all the characters studied.

The mean performance of parents are presented in Table 4 and the mean performance of hybrids are presented in Table 5. Based on the mean performance the lines namely L316 and L64 and the testers namely T308 and T293were good for majority of the characters and can be considered as donor for developing mechanical picking suitable hybrids. The lines namely L64 and L317 can be considered good for plant architecture traits namely plant height, plant width, and boll height as they possess short and compact plant stature.The general combining ability (*gca*) effects of parents are presented in Table 6 and specific combining ability (*sca*) effects of hybrids are furnished in Table 7. The estimates of *gca* effects of parents revealed that the line L64 exhibited significant *gca* effect for the traits like, plant height, plant width, bolls/plant, boll weight and seed cotton yield/plant. Significant *gca* effect for days to fifty per cent flowering, lower boll height, sympodial branches, bolls/plant, boll weight and seed cotton yield/plant was noticed in the parental line L186.Among the testers, T308 recorded significant positive effect for the characters namely days to first boll bursting, plant height,

Table 3. Genetic components for plant architecture and yield traits

Source	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
ó^2 A	0.05	0.12	3.27	0.63	0.07	0.00	0.06	0.00	3.58	0.05	0.01
ó^2 D	1.58	5.78	44.62	96.68	18.81	1.09	8.54	0.13	76.38	5.07	0.14
ó^2 A / ó^2 D	0.03	0.02	0.07	0.01	0.00	0.00	0.01	0.03	0.05	0.01	0.06

Table 4. Mean performance of parents for plant architecture and yield traits

Parents	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Lines											
L64	49.00	104.00	84.00*	56.00	25.00	16.00*	12.00	5.18	54.37	33.85	4.85
L78	51.00	105.00	98.00	63.00	28.00*	15.00*	9.00	4.93	39.79	37.49	5.54
L95	49.00	105.00	88.00*	57.00	20.00	14.00*	11.00	4.45	49.60	34.91	5.20
L129	50.00	102.00	86.00*	49.00	27.00*	12.00	14.00*	5.67*	58.67	37.91	6.08
L186	49.00	102.00	135.00	73.00	31.00*	14.00*	13.00*	5.04	73.41*	30.85	4.31
L316	49.00	99.00*	81.00*	55.00	19.00	12.00	16.00*	4.66	76.13*	40.75*	6.23
L317	49.00	100.00	80.00*	39.00*	22.00	11.00	9.00	4.66	57.41	40.08	5.84
Mean	**49.00**	**102.00**	**93.00**	**56.00**	**25.00**	**13.00**	**12.00**	**4.94**	**58.44**	**36.55**	**5.44**
Testers											
T240	51.00	105.00	104.00	43.00*	28.00*	12.00	13.00*	5.67*	86.03*	38.59	5.72
T293	51.00	104.00	101.00	49.00	26.00	13.00	11.00	6.24*	89.27*	40.84*	6.74*
T308	49.00	104.00	84.00*	41.00*	21.00	13.00	12.00	5.16	68.26	39.60	6.85*
Mean	**50.00**	**104.00**	**96.00**	**44.00**	**25.00**	**13.00**	**12.00**	**5.69**	**81.20**	**38.68**	**6.44**
Mean of parents	**50.00**	**103.00**	**95.00**	**50.00**	**25.00**	**13.00**	**12.00**	**5.32**	**69.82**	**37.61**	**5.94**
S.E (d)	0.62	1.28	1.52	1.11	0.55	0.33	0.36	0.08	1.29	1.01	0.14
CD (p=0.05)	1.72	3.60	4.25	3.11	1.53	0.91	1.00	0.23	3.60	2.82	0.40

* Significant at 5% level

sympodial branches, bolls/plant and seed cotton yield/plant. Similarly, the tester T293 recorded high *gca* effect for days to first boll bursting, plant width, boll weight and seed cotton yield. On overall consideration based on the *gca* effect and high mean values, the lines namely L316, L186, L317 and L64 while the testers namely T308 and T293 were considered as good general combiners and could be desirable parental source for developing suitable hybrids for mechanical harvesting

Plant stature is an important attribute for mechanical harvesting followed by yield and fibre quality traits. The characters taken for the present investigationwere considered as important to determine the suitability of the hybrids for mechanical harvesting (Veerangouda *et al.,* 2012). The hybrids synthesized in the present study were compared against the ideotype range for plant architecture traits and the promising hybrids are selected.The hybrids L317 × T240 falls within the ideotype range for eight characters followed by L316 × T308, L64 × T293 and L64 × T308 for seven characters. The four hybrids L64 × T240, L95 × T240, L95 × T293 and L186 × T240 had six characters in the mechanical picking ideotype range. The hybrid L129 × T293 had only three characters in the ideotype range which indicates unsuitability of this hybrid for mechanical harvesting.

The hybrid L64 × T293 had significant *per se* performance for the traits *viz.,* plant height, plant width, bolls/plant, boll weight, seed cotton yield/plant and lint index. The cross L316 × T308 exhibited significant *per se* performance for traits

Table 5. Mean performance of hybrids for plant architecture and yield traits

Gross	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
L64 × T240	49.00	100.00*	106.00	48.00*	19.00	13.00	14.00	6.23*	74.09	34.69	6.05
L64 × T293	49.00	105.00	98.00*	43.00*	23.00	14.00	22.00*	6.68*	90.67*	37.06	7.08*
L64 × T308	51.00	105.00	95.00*	49.00*	23.00	14.00	17.00	6.11	82.31*	38.62	6.08
L78 × T240	50.00	106.00	117.00	76.00	22.00	15.00*	15.00	5.95	69.14	36.67	6.29
L78 × T293	54.00	106.00	108.00	62.00	27.00*	13.00	13.00	6.13	70.74	38.24	7.25*
L78 × T308	49.00	105.00	98.00*	39.00*	22.00	14.00	14.00	5.35	61.93	34.75	6.14
L95 × T240	50.00	109.00	91.00*	56.00*	28.00*	12.00	14.00	5.72	64.59	38.70	6.24
L95 × T293	51.00	107.00	94.00*	48.00*	24.00	13.00	14.00	5.78	76.00	40.41*	7.25*
L95 × T308	49.00	100.00*	106.00	73.00	19.00	14.00	19.00*	6.24*	88.44*	40.45*	6.61
L129 × T240	50.00	102.00	108.00	64.00	27.00*	13.00	14.00	6.17	67.38	40.06	5.93
L129 × T293	52.00	106.00	121.00	68.00	22.00	15.00*	17.00	6.06	80.45*	38.43	6.66
L129 × T308	53.00	103.00	111.00	72.00	29.00*	14.00	17.00	6.35*	78.24	34.29	6.10
L186 × T240	48.00*	99.00*	113.00	68.00	28.00*	15.00*	23.00*	6.22*	95.08*	35.63	6.05
L186 × T293	50.00	104.00	121.00	61.00	23.00	15.00*	17.00	5.83	91.40*	36.18	6.08
L186 × T308	49.00	105.00	120.00	66.00	34.00*	15.00*	19.00*	6.46*	83.37*	31.62	5.62
L316 × T240	49.00	107.00	100.00*	66.00	27.00*	12.00	17.00	5.03	60.48	39.02	6.13
L316 × T293	50.00	102.00	107.00	64.00	21.00	15.00*	17.00	5.27	65.91	37.70	6.34
L316 × T308	50.00	102.00	94.00*	61.00	16.00	14.00	21.00*	5.76	84.09*	41.75*	7.26*
L317 × T240	48.00*	102.00	100.00*	51.00*	28.00*	14.00	19.00*	5.23	58.60	36.85	5.26
L317 × T293	52.00	104.00	97.00*	52.00*	23.00	12.00	12.00	6.35*	67.96	35.49	6.13
L317 × T308	49.00	104.00	100.00*	66.00	19.00	15.00*	19.00*	5.95	87.69*	41.39*	6.23
Grand mean	**50.00**	**104.00**	**105.00**	**60.00**	**24.00**	**14.00**	**17.00**	**5.95**	**76.12**	**37.52**	**6.32**
S.E (d)	0.62	1.28	1.52	1.11	0.55	0.33	0.36	0.08	1.29	1.01	0.14
CD (P=0.05)	1.72	3.60	4.25	3.11	1.53	0.91	1.00	0.23	3.60	2.82	0.40

* Significant at 5% level

Table 6. General combining ability effects of parents for plant architecture and yield traits

Parents	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Lines											
L64	-0.44 ns	-0.57 ns	-5.49 **	-12.86 **	-2.24 **	-0.29 ns	0.98 **	0.39 **	6.23 **	-0.73 ns	0.08 ns
L78	0.78 *	1.43 *	2.84 **	-0.75 ns	-0.35 ns	0.27 ns	-3.13 **	-0.14 **	-8.85 **	-0.97 ns	0.24 **
L95	-0.11 ns	1.32 ns	-8.16 **	-0.75 ns	-0.46 ns	-0.84 **	-1.35 **	-0.03 ns	0.22 ns	2.33 **	0.38 **
L129	1.56 **	-0.13 ns	8.06 **	8.37 **	1.87 **	0.16 ns	-0.79 **	0.24 **	-0.77 ns	0.07 ns	-0.09 ns
L186	-1.00 **	-1.35 ns	13.06 **	5.14 **	4.43 **	0.94 **	2.87 **	0.23 **	13.83 **	-3.05 **	-0.41 **
L316	-0.33 ns	-0.13 ns	-4.60 **	4.25 **	-2.68 **	-0.17 ns	1.54 **	-0.59 **	-5.96 **	1.97 **	0.25 **
L317	-0.44 ns	-0.57 ns	-5.71 **	-3.41 **	-0.57 ns	-0.06 ns	-0.13 ns	-0.10 *	-4.70 **	0.39 ns	-0.45 **
SE	0.35	0.69	0.89	0.67	0.29	0.20	0.22	0.05	0.81	0.59	0.09
Testers											
T240	-0.89 **	-0.17 ns	0.11 ns	1.51 **	1.59 **	-0.56 **	-0.29 ns	-0.15 **	-6.21 **	-0.15 ns	-0.33 **
T293	1.16 **	0.87 ns	1.40 *	-2.54 **	-0.84 **	0.11 ns	-0.81 **	0.07 *	1.47 **	0.12 ns	0.36 **
T308	-0.27 ns	-0.70 ns	-1.51 *	1.03 *	-0.75 **	0.44 **	1.10 **	0.08 **	4.75 **	0.03 ns	-0.03 ns
SE	0.23	0.45	0.58	0.44	0.19	0.13	0.15	0.03	0.53	0.39	0.06

**– Significant at 1% level, *– Significant at 5% level, ns – Non Significant like plant height, bolls/plant, seed cotton yield, ginning per cent and lint index. Hence, the aforesaid hybrids are suitable for mechanical harvesting as they performed well for maximum number of plant architecture and yield traits. Based on *sca* effects, the hybrid L316 × T308 had significant *sca* effects for plant height, plant width, bolls/plant, boll weight, seed cotton yield/ plant, ginning percent and lint index. The hybrid L64 × T293 recorded significant *sca* effects for days to fifty per cent flowering, plant height, bolls, boll weight, seed cotton yield and lint index, while L78 × T240 exhibited significantly positive effects for four traits namely sympodial branches, bolls/plant, boll weight and seed cotton yield/ plant.

Hence, the hybrids *viz.*, L316 × T308, L64 × T293and L95 × T240 were considered as good specific combiners and could be used for heterosis breeding programme to develop hybrids for mechanical harvesting. Since cotton is an often cross pollinating crop, varietal crosses can be easy by hand emasculation. Hence, these hybrids could be utilized in heterosis breeding programme. The hybrid L64 × T308 could be recommended for recombination breeding as its parents showed significant *gca* effects and the hybrid recorded, non significant *sca* effects traits namely plant height, bolls/plant, boll weight and seed cotton yield

Table 7. Specific combining ability effects of hybrids for plant architecture and yield traits

Cross	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
L64 × T240	0.11 ^{ns}	-2.05 ^{ns}	6.11 **	-0.62 ^{ns}	-4.14 **	-0.33 ^{ns}	-3.27 **	0.04 ^{ns}	-2.05 ^{ns}	-1.95 ^{ns}	-0.02 ^{ns}
L64 × T293	-1.94 **	0.24 ^{ns}	-3.17 *	-0.90 ^{ns}	1.95 **	0.33 ^{ns}	5.25 **	0.27 **	6.85 **	0.15 ^{ns}	0.32 *
L64 × T308	1.83 **	1.81 ^{ns}	-2.94 ^{ns}	1.52 ^{ns}	2.19 **	0.00 ^{ns}	-1.98 **	-0.32 **	-4.80 **	1.80 ^{ns}	-0.29 ^{ns}
L78 × T240	0.22 ^{ns}	0.62 ^{ns}	9.44 **	15.60 **	-3.03 **	1.44 **	1.17 **	0.29 **	8.08 **	0.27 ^{ns}	0.06 ^{ns}
L78 × T293	1.84 **	-0.43 ^{ns}	-1.17 ^{ns}	5.65 **	4.06 **	-0.89 *	0.03 ^{ns}	0.25 **	2.00 ^{ns}	1.56 ^{ns}	0.33 *
L78 × T308	-2.06 **	-0.19 ^{ns}	-8.27 **	-21.25 **	-1.03 *	-0.56 ^{ns}	-1.21 **	-0.55 **	-10.09 **	-1.83 ^{ns}	-0.39 *
L95 × T240	1.11 ^{ns}	3.73 **	-6.22 **	-4.73 **	3.08 **	-0.78 *	-1.60 **	-0.04 ^{ns}	-5.54 **	-1.01 ^{ns}	-0.13 ^{ns}
L95 × T293	0.06 ^{ns}	0.68 ^{ns}	-4.51 **	-8.02 **	0.84 ^{ns}	0.22 ^{ns}	-0.75 ^{ns}	-0.20 *	-1.81 ^{ns}	0.44 ^{ns}	0.19 ^{ns}
L95 × T308	-1.17 ^{ns}	-4.41 **	10.73 **	12.75 **	-3.92 **	0.56 ^{ns}	2.35 **	0.24 **	7.35 **	0.57 ^{ns}	-0.06 ^{ns}
L129 × T240	-0.56 ^{ns}	-1.49 ^{ns}	-5.44 **	-5.51 **	-0.92 ^{ns}	-0.78 *	-1.49 **	0.13 ^{ns}	-1.77 ^{ns}	2.62 *	0.03 ^{ns}
L129 × T293	-0.60 ^{ns}	1.46 ^{ns}	6.27 **	2.87 *	-3.16 **	0.89 *	1.70 **	-0.20 *	3.63 *	0.72 ^{ns}	0.07 ^{ns}
L129 × T308	1.16 ^{ns}	0.03 ^{ns}	-0.83 ^{ns}	2.63 *	4.08 **	-0.11 ^{ns}	-0.21 ^{ns}	0.07 ^{ns}	-1.86 ^{ns}	-3.33 **	-0.10 ^{ns}
L186 × T240	0.00 ^{ns}	-3.27 **	-4.78 **	1.38 ^{ns}	-1.81 **	0.44 ^{ns}	3.51 **	0.20 *	11.35 **	1.30 ^{ns}	0.46 **
L186 × T293	-0.05 ^{ns}	0.68 ^{ns}	1.27 ^{ns}	-1.24 ^{ns}	-4.71 **	0.11 ^{ns}	-1.97 **	-0.41 **	-0.02 ^{ns}	1.58 ^{ns}	-0.20 ^{ns}
L186 × T308	0.05 ^{ns}	2.59 *	3.51 *	-0.14 ^{ns}	6.52 **	-0.56 ^{ns}	-1.54 **	0.20 *	-11.33 **	-2.89 **	-0.26 ^{ns}
L316 × T240	0.00 ^{ns}	3.51 **	-0.11 ^{ns}	0.94 ^{ns}	3.63 **	-1.11 **	-1.16 **	-0.17 *	-3.47 *	-0.32 ^{ns}	-0.12 ^{ns}
L316 × T293	-0.71 ^{ns}	-2.54 *	4.94 **	2.98 *	0.73 ^{ns}	1.22 **	-0.63 ^{ns}	-0.15 ^{ns}	-5.72 **	-1.91 ^{ns}	-0.60 **
L316 × T308	0.71 ^{ns}	-0.97 ^{ns}	-4.83 **	-3.92 **	-4.37 **	-0.11 ^{ns}	1.79 **	0.32 **	9.19 **	2.23 *	0.72 **
L317 × T240	-0.89 ^{ns}	-1.05 ^{ns}	1.00 ^{ns}	-7.06 **	3.19 **	1.11 **	2.84 **	-0.46 **	-6.60 **	-0.91 ^{ns}	-0.28 ^{ns}
L317 × T293	1.40 *	-0.10 ^{ns}	-3.62 *	-1.35 ^{ns}	0.29 ^{ns}	-1.89 **	-3.63 **	0.44 **	-4.92 **	-2.54 *	-0.11 ^{ns}
L317 × T308	-0.51 ^{ns}	1.14 ^{ns}	2.62 ^{ns}	8.41 **	-3.48 **	0.78 *	0.79 *	0.02 ^{ns}	11.53 **	3.45 **	0.39 *
SE	0.61	1.19	1.55	1.64	0.50	0.34	0.39	0.08	1.40	1.03	0.15

**– Significant at 1% level, *– Significant at 5% level, ^{ns} – Non Significant DFF– Days to fifty per cent floweringDBB– Days to first boll burstingPH– Plant heightPW– Plant width HLB– Height of lower most boll NSY– Number of sympodial branches per plantNB– Number of bolls per plantBW– Boll weightSCY– Seed cotton yield per plant GP– Ginning per centLI– Lint index

REFERENCES

Business Line, India Faces Uphill Task in Mechanizing Cotton Farming, Dec. 13, 2012.

Christopher. L., Cheatham, J. N., Jenkins, Jack, C., Mc Carty, J. Clarence, E. Waston and J. Wu. 2003. Genetic variance and combining ability of crosses of American cultivars, Australian cultivars and wild cottons. *J. Cotton Sci.,* **7 :** 16-2

Giri, R.K., K.S. Nirania, Y. Dutt, R.S. Sangwan and P.P. Jain 2006. Heterosis for seed cotton yield and its contributing traits in upland cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.,* **20 :** 39–47

Kempthorne, O. 1957. *An Introduction to Genetic Sstatistics.* John Wiley and Sons, Inc. New York.

Muthumilselvan, M., Rangaswamy, K., Ananthakrishnan, D. and Manian, R. 2007. Mechanical Picking of Cotton. *Agricultural Review,* **28 :** 118-26.

Panse, V.G. and P.V. Sukhatme. 1964. *Statistical Methods for Agricultural Workers,* 2ndEdn., ICAR, New Delhi. p361.

Prasad, J., TarunKapur, Sandhar, N. S., Majumdar, G., Patil, P. G., Shukla, S. K., Jaiswal, B. N. and Patil, A. B., 2004. Test code and procedure for spindle type cotton picker. NATP, CIAE, Bhopal

Punitha, D., T.S. Raveendran and P. Vindhiyavarman. 2008. Combining ability studies in hybrid cotton(*Gossypium hirsutum* L.). *Intl. J. Plant Sci.,* **3 :** 40–45.

Subba Reddy, B. and N. Nadarajan. 2006. Combining ability analysis for yield and other economic traits in white × colour linted crosses of *Gossypium hirsutum* cotton. *J. Cotton Res. Dev.,* **20 :** 25–31.

Veerangouda, M., Asokan, D., and Guruswamy, T. 2012. Comparative evaluation of biometric parameters of cotton at kapas picking stage. *Karnataka J. Agric. Sci.,* **25 :** 363-66

CROP PRODUCTION, MECHANIZATION AND ECONOMIC DEVELOPMENT

29

Productivity and profitability of BG II cotton hybrids as influenced by different planting geometry and nitrogen levels under rainfed condition in vertisols of Andhra Pradesh

S. JAFFAR BASHA, A. S. R. SARMA AND Y. RAMA REDDY

Acharya N.G.Ranga Agricultural University, Regional Agricultural Research Station, Nandyal - 518502.

E-mail: shaik.jaffarbasha@gmail.com

ABSTRACT : A field experiment was conducted during *kharif,* 2011 at Regional Agricultural Research Station, Nandyal, Andhra Pradesh, India for optimization of nutrient requirement and plant geometry for ruling BG II cotton hybrids of this region under rainfed condition in vertisols. Higher monopodia/plant(1.34), kapas yield (2026 kg/ha), oil percentage (18.32), net returns ('47,592 /ha) and benefit cost ratio (BCR) of 2.27 were observed under closer spacing (90 x 45 cm). The number of bolls/plant (27.74), *kapas* yield (1983 kg/ha), net returns ('48,286/ha) and BCR of 2.38 was observed with Bunny BG II hybrid and was *on par* with Mallika BG II (25.34, 1969 kg/ha, '47,656 /ha and 2.36, respectively). Higher boll weight (4.82 g) was observed in Mallika BG II. *Kapas* yield (1863 kg/ha), net returns ('42,446 /ha) and BCR of 2.18 was significantly higher with the application of 180 N kg/ha.

Key words : BG II cotton hybrid, nitrogen level, plant geometry, rainfed, vertisols

Cotton is said to be "King of Fibres". In fact it is true because cotton has a great importance in global economy. Cotton is grown in about 80 countries but only five countries viz., China, India, USA, Pakistan and Brazil accounted for about 81 per cent of the global area and provided 75 per cent of the world's cotton in 2009-2010. During 2007-2008, these countries together produced 30.2 million tonnes (m t) of lint. In 2013-2014, the global area and production of cotton were 33.1 million ha and 117 million bales respectively with a productivity of 766 kg lint /ha whereas cotton in India was cultivated in 126.5 lakh ha with production of 400 lakh bales with a productivity of 537 kg lint / ha.Transgenic cotton was introduced for commercial cultivation in 1996 in the USA, Australia, China, Mexico and Argentina (James, 2006). The global adoption of transgenic cotton has risen dramatically from 0.8 (1996) to 15.5 m ha in (2008). In India cotton is produced in 117.27 lakh ha with production of 390 lakh bales and productivity of 565.36 kg/ha during 2013-2014. In India around 85 per cent of the cotton area is under *Bt* hybrids. Agronomic performance of *Bt* cultivars may vary substantially from their non *Bt* counterparts (Jenkins *et al.,* 1997). Today, biotech cotton confers improved pest (bollworm) management and retention of early formed fruiting parts leading to higher and earlier boll load. The plants are also early in maturity. In India, *Bt* hybrids had short stature along with inbuilt resistance to bollworm leads to retention of early formed fruiting parts and promotes earliness by 20-30 days (Mayee *et al.,* 2004). The plant had shallower roots and produced less dry matter and also retain more bolls particularly the early formed ones at lower nodes. Higher sink in *Bt* cotton leads to lower source to sink ratio, faster senescence and crop maturity compared to the non *Bt* version (Hebbar *et al.,* 2007). Early fruit load, coupled with faster fruit load could constrain nutrient supply leading to smaller plants and may lower the yield potential (ICAC, 2010). To overcome these potential problems changes in agronomic practices are needed for achieving maximum benefits from the technology. Spacing is an important factor which influenced the yield as well as plant stand. There is a positive relationship between optimum plant population and yield (Rao, 1985). The productivity of cotton can be obtained with suitable agronomic practices like maintenance of optimum plant density and use of optimum dose of fertilizer. Hence, keeping this in view, the present study was carried out to find out the suitable plant geometry and nitrogen level in popularly grown BG II cotton hybrids.

A field study was carried out during *kharif* 2011 at the research farm of Regional Agriculture Research Station, Nandyal, Kurnool District, Andhra Pradesh. The soil was deep black with pH 8.51, low in available nitrogen (138 kg/ha), high in available phosphorous (43 kg/ha) and potassium (408 kg/ha). A total of 589.9 mm rainfall was received in 35 rainy days during the crop period. The experiment was laid out in split split plot design with plant geometry as main plots, BG II hybrids as sub plots and nitrogen levels as sub sub plots and replicated thrice. The main plot treatments consist of two plant geometries *viz.,* 120 x 60 (normal spacing of locality) and 90 x 45 cm (higher density). The sub plot treatments consist of three BG II hybrids *viz.,* Bunny, Rasi and Mallika. Three nitrogen levels 120, 150 and 180 kg/ha were allocated in sub sub plots. Sowing was done on 07.08.2011 by dibbling method. Entire phosphorous (60 kg/ha) as single super phosphate and potassium (60 kg/ha) as murate of potash were applied as basal. Nitrogen as urea was applied in four splits at basal, 30, 60 and 90 days after sowing. All other recommended package of practices was followed during the crop season. Plant protection measures were taken up as per requirement especially for sucking pests during the crop growth. Data pertaining to yield attributing characters like plant height, monopodia, sympodia, bolls/plant and boll weight were recorded from randomly selected five plants in each treatment and seed cotton yield was recorded from the net plot. Fiber characters like strength, fineness, uniformity and elongation of each treatment were measured using spinlab high volume instrument (HVI-900). The data was statistically analyzed by standard procedure of Panse and Sukhatme (1967).

Effect of plant geometry: There was no significant effect of plant geometry on sympodia and bolls/plant, ginning percentage, lint index and seed index (Table 1). Higher plant height (79.16 cm), monopodia/plant (1.34), *kapas* yield (2026 kg/ha), oil percentage (18.32) were observed under 90 x 45 cm. Similar differences in plant height due to plant geometries were reported by Bhalerao *et al.,* (2008). A closer geometry (90 x 45 cm) recorded 33.64 per cent higher seed cotton yield (2026 kg/ha) as compared to wider geometry of 120 x 60 cm (1516 kg/ha). Higher seed cotton yield under closer geometry was observed due to significantly higher plant population (Table 1). Similar effect of higher plant density has also been reported by Giri and Gore (2006) and Buttar *et al.,* (2010). Plant geometry did not significantly influence quality characters *viz.,* staple length, uniformity ratio, micronaire, strength. Net returns (‘47,592 /ha) and BCR of 2.27 were observed under closer spacing (90 x 45 cm) (Table 2).

Effect of BG II hybrids: Higher plant

Table 1: Yield parameters and yield of cotton hybrids as influenced by plant geometry and nitrogen levels

Treatment	Plant stand/ha	Plant height (cm)	Mono-podia/ plant	Symp-odia/ plant	Bolls/ plant	Boll weight (g)	*Kapas* yield (kg/ha)	Gin-ning (%)	Lint index	Seed index	Oil (%)
Plant geometry (cm)											
120 × 60	13181	74.94	1.23	14.48	26.81	3.82	1516	32.63	5.14	10.70	17.98
90 × 45	23700	79.16	1.34	14.08	24.50	4.32	2026	33.33	5.55	11.25	18.32
S.Em±	270	0.30	0.015	0.51	1.68	0.08	16	0.20	0.13	0.25	-
C.D. (p=0.05)	1643	1.87	0.095	NS	NS	0.50	97	NS	NS	NS	-
BG II hybrids											
Bunny	18346	80.18	0.96	15.07	27.74	4.14	1983	32.89	5.16	11.16	19.28
Rasi	18388	72.17	2.01	12.9	23.88	3.25	1361	33.00	4.50	9.33	16.66
Mallika	18587	78.81	0.90	14.87	25.34	4.82	1969	33.06	6.38	12.44	18.51
S.Em±	239	1.99	0.08	0.72	0.82	0.14	121	0.29	0.18	0.27	-
C.D. (p=0.05)	NS	6.94	0.26	NS	2.69	0.46	393	NS	0.60	0.90	-
Nitrogen levels (kg/ha)											
120	18300	75.37	1.23	14.24	24.90	4.06	1701	32.94	5.72	11.83	18.20
150	18465	77.15	1.34	14.33	25.11	4.08	1750	33.50	4.94	10.11	18.20
180	18556	78.63	1.30	14.27	26.96	4.06	1863	32.50	5.38	11.00	18.03
S.Em±	219	1.01	0.79	0.41	0.69	0.08	55	0.21	0.24	0.41	-
C.D. (p=0.05)	NS	2.96	NS	NS	2.02	NS	161	0.61	0.72	1.21	-
CV (%)	5.04	5.59	25.91	12.2	13.14	9.09	13.21	2.72	19.61	16.13	-

height (80.18cm) was observed in Bunny and is on par with Mallika (78.81cm). Significantly higher monopodia/plant was observed in Rasi (2.01).The sympodia/plant was not significantly influenced by BG II hybrids. The bolls/plant were significantly more with Bunny (27.74) hybrid and was on par with Mallika (25.34). Higher boll weight(4.82) was observed in Mallika. Kapas yield was significantly more with the Bunny (1983 Kg /ha) and is *on par* with Mallika (1969 Kg /ha) which was 45.7 per cent higher than mallika (1361 Kg /ha), primarily owing to significantly improved number of sympodia, bolls/plant and boll weight. Sisodia and Khamparia (2007) also recorded significantly higher cotton yield due to more number of sympodia and bolls/plant. The ginning percentage was not significantly influenced by BG II hybrids. Higher lint index (6.38) and seed index (12.44) was observed in Mallika. Higher oil per cent (19.28) was observed in Bunny. Among the hybrids, Bunny recorded higher staple length (31.58) and higher micronaire (3.71). Mallika recorded higher strength (24.63) and uniformity ratio (51.54). Optimum source indices at the desired growth and reproductive phases resulted in better sink development, which ultimately reflect in higher production efficiency of improved genotypes. Net returns (‘48,286 /ha) and BCR of 2.38 was observed with Bunny BG II hybrid.

Effect of nitrogen levels: Taller plants (78.63 cm) were observed with the application of 180 kg N /ha. The monopodia/plant, sympodia/ plant and boll weight were not significantly influenced by different fertilizer levels. Kapas yield (1863 Kg /ha) was significantly more with the application of 180 kg N /ha and is *on par*

Table 2. Quality parameters and economics as influenced by plant geometry and nitrogen levels

Treatment	Staple length (mm)	Strength (g/tex)	Uniform ratio (%)	Micro-naire value	Gross returns (/ha)	Cost of cultivation (/ha)	Net returns (/ha)	BC ratio
Plant geometry (cm)								
120 × 60	29.99	23.03	50.99	3.56	63672	35000	28672	1.82
90 × 45	30.07	22.42	50.75	3.55	85092	37500	47592	2.27
S.Em±	0.09	0.28	0.60	0.08	-	-	-	-
C.D. (p=0.05)	NS	NS	NS	NS	-	-	-	-
BG-II hybrids								
Bunny	31.58	22.77	49.87	3.71	83286	35000	48286	2.38
Rasi	27.81	20.77	51.19	3.41	57162	35000	22162	1.63
Mallika	30.71	24.63	51.54	3.54	82656	35000	47656	2.36
S.Em±	0.26	0.17	0.24	0.08	-	-	-	-
C.D. (p=0.05)	0.87	0.56	0.80	0.27	-	-	-	-
Nitrogen levels (kg/ha)								
120	29.85	22.95	50.83	3.57	71442	35000	36442	2.04
150	29.76	22.62	51.01	3.59	73500	35400	38100	2.07
180	30.48	22.60	50.77	3.50	78246	35800	42446	2.18
S.Em±	0.11	0.17	0.36	0.06	-	-	-	-
C.D. (P=0.05)	0.33	NS	NS	NS	-	-	-	-
CV (%)	3.78	3.29	3.00	7.54	-	-	-	-

Cotton - ‘ 5000/q; Urea - ‘ 5.5/kg

with 150 kg N /ha (1750 Kg /ha). The increase in yield may be attributed to favourable effect of nitrogen application on yield attributing characters i.e. plant height(78.63 cm) and bolls/ plant(26.96). Similar positive response was observed by Palomo *et al.,* (2003), Prasad and Siddique (2004), Meena *et al.,* (2007) and Singh and Gill (2007). It may be due to increased availability of nutrients which helped the plant to attain its maximum yield potential. The above findings are in accordance with the results reported earlier by Khamparia *et al.* (2009).The ginning percentage (33.5) was observed higher under 150 kg N /ha. Higher seed index (5.72) and lint index (11.83) was observed with the application of 120 kg N /ha. Application of 180 kg N /ha reported higher staple length (30.48). The other quality characters like micronaire, strength and elongation ratio were unaffected by fertilizer levels. Net returns ('42,446 /ha) and BCR of 2.18 was significantly higher with the application of 180 N kg/ha. Similar finding was reported by Basavanneppa (2005).

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REFERENCES

Basavanneppa, M. A. 2005. Productivity and profitability of cotton influenced by fertilizer management under Tungabhadra Project area of Karnataka. *J. Cotton Res. Dev.,* **19**:66-68.

Bhalerao, P. D., Gawande, P. P. Ghatol P. U. and Patil B. R. 2008. Performance of *Bt* cotton hybrids for various spacing under rainfed condition. *Agric. Sci. Digest,* **28** : 54-56.

Buttar, G. S., Sekhon, K. S. and Singh Sudeep, 2010. Effect of different spacing and nitrogen levels on growth and yield attributes of American cotton (*Gossypium hirsutum* L.) *Bt* hybrids under irrigated conditions. *J. Cotton Res. Dev.,* **24**:73-75.

Giri, A. N. and Gore, S. B. 2006. Effect of plant densities and NPK levels on yield of newly released desi varieties of cotton (*Gossypium arboretum* L.). *J. Cotton Res. Dev.,* **20**:77-79.

Hebbar, K.B., Rao, M. R. K and Khadi, B.M. 2007. Synchronized boll development of *Bt* cotton hybrids and their physiological consequences. *Curr. Sci.,* **93:** 693-95**.**

ICAC, 2010. Biotech cotton also requires agronomic changes. *ICAC Recorder,* **37:** 16.

James, C. 2006. Global Status of Commercialized Biotech/GM Crops: 2006. *ISAAA Briefs No. 35,* International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY.

Jenkins, J.N., McCarty, Jr. J.C., Buehler, R.E., Kiser, J., Williams, C. and Wofford, T. 1997. Resistance of cotton with î-endotoxin genes from *Bacillus thuringiensis* var. *kurstaki* on selected lepidopteran insects. *Agron. J.,* **89:** 768-80.

Khamparia S. K., Upadhaya, A. Shah M.S. and Sisodia R.I. 2009. Evaluation of agronomic requirements of *Bt* cotton hybrid under different spacing and fertility levels in rainfed conditions. National symposium on *"Bt Cotton: Opportunities and Prospects"* Crop Production, 17-19 November, 2009, CICR, Nagpur, pp. 85.

Mayee, C.D., Phundan Singh, Punit Mohan and Agarwal, D.K. 2004. Evaluation of *Bt* transgenic intra hirsutum hybrids for yield and fibre properties. *Ind. J. Agri. Sci.,* **74 :** 746-47.

Meena,R.L., Babu, V.R. and Nath, A.2007. Effect of fertilizer management on cotton under saline soils of Gujarat. *Bharatiya Krishi Anusandhan Patrika,* **22**:206-10.

Palomo, G., Gaytan, M. A., Espinoza, B. A., Martinez, A. H. J. and Jasso, C. D. 2003. Nitrogen doses and irrigation number on cotton yield and seed quality. *Revista Fitotecnia Mexicana,* **26**:95-99.

Panse, V.G. and Sukhatme, P.V. 1967. *Statistical Methods of Agricultural Workers.* 2 nd edition ICAR, New Delhi.

Prasad, M. and Siddique, M. R. B. 2004. Effect of nitrogen and mepiquat chloride on yield and quality of upland cotton (*Gossypium hirsutum* L.). *Indian J. Agri. Sci.,* **74**:560-62.

Rao, M.H. 1985. Effect of planting time and plant population on two promising genotypes to American upland cotton. *Indian J. Agron.*, **27** : 307-09.

Singh Kulvir and Gill, J.S.2007. Effect of different spacing and nitrogen levels on growth and yield attributes of desi cotton (*Gossypium arboretum* L.) hybrids. *J. Cotton Res. Dev.,* **21**:77-79.

Sisodia, R. I. and Khamparia, S. K. 2007. American cotton varieties as influenced by plant densities and fertility levels under rainfed conditions. *J. Cotton Res. Dev.,* **21**:35-40.

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Agronomic evaluation of popular *Bt* cotton hybrids in Marathwada region under rainfed condition

A. D. PANDAGALE, K. S. BAIG, T. B. NAMADE AND S. S. RATHOD

Vasantrao Naik Marathwada Krishi Vidyapeeth, Cotton Research Station, Nanded - 431 601

E-mail : arvindpandagale@yahoo.co.in

ABSTRACT : A field experiment was conducted during year 2013-14 with an objective to find out suitable spacing and fertilizer levels for popular *Bt* cotton hybrids under rainfed condition. The experiment was conducted at Cotton Research Station Nanded (M.S.) and was laid out in split split plot design with three replications. Two spacings (120 x 45 and 90 x 45 cm) in sub plot and three fertilizer levels (100%, 125% and 150%) were evaluated in sub sub plot for three popular *Bt* cotton hybrids (BG II) among farmers in main plot. The rainfall to the tune of 1,337 mm (52 per cent more than average) was received which was distributed in 56 rainy days during the season. The results indicated that hybrid Ajeet 155 *Bt* recorded highest seed cotton yield (3302 kg / ha), and boll weight (4.30 g) and was *at par* with Dr. Brent (MRC 7347). Comparatively dwarf plants with less number of branches in hybrid Mallika *Bt* resulted to lower seed cotton yield.

Reduction in number of bolls and boll weight was noticed in closer plant spacing (90 x 45 cm) however was compensated for seed cotton yield (3239 kg / ha) by 6.82 per cent because of higher plant population. This resulted to increased monetary values in closer spacing (90 x 45 cm) in terms of GMR (Rs 1,61,380/h) and NMR (Rs 1,03,080/ha) significantly. The interaction of hybrid x spacing revealed that Mallika hybrid performed better under (90 X 45 cm) spcing where as hybrids Ajeet 155 *Bt* and Dr Brent *Bt* were similer under both spacings. The *Bt* cotton hybrids responded to increase in growth, yield and attributing characters due to increase of fertilizer levels. However, the 150 per cent RDF level recorded highest seed cotton yield (3332 kg/ha), GMR (Rs 1,65,190/ha) and NMR (Rs1,02,880/ha) and was found *at par* with 125 per cent RDF.

Key words : *Bt* cotton hybrid, economics, fertilizer, spacing, yield

Cotton crop plays dominant role in industrial and agricultural economy. It is grown under rainfed condition on more than 65 per cent area in India. Cotton cultivation in Maharashtra state is gone up after introduction of transgenic cotton, presently grown on about 41.92 lakh ha (2014-2015). *Bt* cotton use spread rapidly, resulting reduced bollworm infestation and insecticidal use which greatly increased productivity. Cotton is the most important commercial crop of Marathwada region for the last 50 years in the state which covers 41 per cent state area of the crop. Cotton yields in rainfed ecosystem are low owing to erratic rainfall, uneven distribution and moisture stress at reproductive stages leading to inconsistent yields.

Maximum yield of *Bt* cotton can be realized by adopting new and high yielding *Bt* cotton hybrids with suitable agronomic practices *viz.*, optimum plant density and fertilizer management. More than 100 *Bt* cotton hybrids are available in regional market which are having greater variation in growth habit, duration and adoptability to agronomic practices. Preliminary studies on *Bt* cotton have shown that they mature earlier than non *Bt* cotton. This early senescence and increased productivity may require higher nutrient requirement to support boll number and higher yields. Establishment of acceptable population of cotton seedling is paramount to obtain high yield. Optimum plant population varies by location, environment, cultivar and growers performance. High and suitable productivity of cotton can be achieved with suitable plant population associated with balanced nutrition and consequently its availability in soil.

Different *Bt* cotton hybrids differ in their productivity under various plant geometries and should be fertilized more with closer spacing for higher yields. But research studies on this aspect are less. Keeping in view of the above facts, the present investigation was planned to find out optimum plant geometry and economical fertilizer requirement for popular *Bt* cotton hybrids under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted at Cotton Research Station, Nanded to identify optimum plant spacing and fertilizer requirement for three popular *Bt* cotton hybrids among farmers under rainfed condition in Mararthwada region for the year 2013-2014. The soil of experimental site was clay loam having pH 7.75. The soil was low in organic carbon (0.75%) and available nitrogen (105.0 kg/ha); medium in phosphorus (10.35% kg / ha) and high in potassium (530.80 kg / ha) content. The experiment was laid out in split split plot design with three replications. Sowing was done on June 18th, 2013. Three *Bt* cotton hybrids (BG II) on farmers field *viz.* Mallika (NCS 207), Ajeet 155 and Dr. Brent (MRC 7347) in main plot; were studied in normal spacing *i.e.* 120 x 45 cm and closer spacing with higher population *i.e.* 90 x 45 cm in sub plot. Three fertilizer levels RDF (120:60:60 NPK kg / ha), 125 per cent RDF and 150 per cent RDF were tested for response on growth, yield and economics of the *Bt* cotton hybrids. Cumulative rainfall 1337 mm (52% excess over average) was received during June - December 2013 well distributed in 56 rainy days.

RESULTS AND DISCUSSION

Effect of *Bt* cotton hybrids : The *Bt* cotton hybrid Ajeet 155 recorded highest seed cotton yield (3302 kg/ha) reflecting an increase of 12 per cent over Mallika *Bt*, but was *on par* with *Bt* hybrid Dr. Brent (3199 kg/ha). Pendharkar *et al.,* (2010) also reported higher yield from Ajeet 155 *Bt*. This is mainly due to significant increase in yield contributing characters noticed in Ajeet 155 *Bt*. Significantly higher boll weight (4.29 g) and yield/plant (166.27 g) were registered with Ajeet 155 *Bt* when compared with Mallika *Bt*. Higher number of bolls/plant (45.69) were recorded from *Bt* hybrid Dr. Brent which contributed to increased yield of that hybrid over Mallika. Higher number of yield contributing characters in Ajeet 155 may be attributed due to taller plant height (180.51 cm) associated with greater number of sympodial branches (20.27) over Mallika *Bt* (Table 1).

Increase in seed cotton yield of Ajeet 155 *Bt* resulted to significantly higher gross as well as net monetary returns and B:C ratio (Rs 1,64,550/ha, Rs 1,06,790/ha and 2.55, respectively) over Mallika *Bt*.

Effect of spacing : Significantly higher seed cotton yield (3239 kg/ha) was registered with closer spacing (90 x 45 cm) and it was 6.40 per cent greater over normal spacing (120 x 45

Table 1. Plant growth and yield contributing characters as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Boll weight (g)	Yield/ plant (g)	No. of Bolls/ plant
Main plot : *Bt* cotton hybrids						
H_1: Mallika	153.84	0.93	17.97	4.15	142.33	35.87
H_2: Ajeet 155	180.51	1.08	20.27	4.29	166.27	43.07
H_3: MRC 7347	174.32	1.12	19.81	3.59	153.65	45.69
SE+	4.46	0.04	0.056	0.03	4.06	0.69
CD (p=0.05)	17.50	0.15	2.19	0.11	15.90	2.72
Sub-plot: Plant geometry						
G1 : Normal spacing (120 x 45 cm)	166.24	1.08	19.47	4.15	168.65	44.64
G2 : Closer spacing (90 x 45 cm)	172.87	1.01	19.23	3.87	139.52	38.44
SE+	4.53	0.02	0.04	0.06	1.90	0.31
CD (p=0.05)	N.S.	N.S.	N.S.	0.20	6.56	1.06
Sub sub plot : Nutrient levels						
F_1: RD - NPK (100:50:50)	161.88	0.98	17.92	3.82	144.90	38.37
F_2: 125 (% RD) – NPK	171.11	1.03	19.30	4.04	153.32	41.81
F_3: 150 (% RD) – NPK	175.62	1.12	20.82	4.17	164.02	44.44
SE+	3.02	0.03	0.61	0.06	3.74	1.12
CD (p=0.05)	8.80	0.10	1.78	0.17	10.89	3.26
Interaction H x G						
SE+	7.85	0.04	0.61	0.10	3.29	0.53
CD (p=0.05)	N.S.	N.S.	N.S.	0.34	11.36	1.84
Interaction H x F						
SE+	5.23	0.06	1.06	0.10	6.47	1.94
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction G x F						
SE+	4.27	0.05	0.86	0.08	5.28	1.58
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	15.40	4.60
Interaction H x G x F						
SE+	7.40	0.08	1.50	0.14	9.15	2.74
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	26.67	N.S.
C.V. (%)	7.55	13.79	13.43	6.21	10.29	11.41
Grand mean	**169.56**	**1.04**	**19.35**	**4.01**	**154.08**	**41.54**

cm). The increased yield in closer plant spacing was evident due to higher plant population (24,691 plants/ha) over normal (18,518 plants/ha), although there was significant reduction in bolls/plant and boll weight in closer spacing. Greater number of bolls (44.64)/plant and boll weight (4.15 g) in normal spacing could be attributed to more available space, better aeration, adequate interception of light as well as lesser competition of nutrients to plants in normal spacing with lower plant density. Similar results were reported by Raghu Rami Reddy and Gopinath (2008), Sree Rekha and Pradeep (2012). The plant growth characters were not found to differed due to spacing. Similar results were reported by Malavath *et al.,* (2014).

The closer spacing (90 x 45 cm) with higher plant population was significantly remunerative in respect of GMR (Rs 1,61,380/ha) and NMR (Rs 1,03,080/ha) over normal

Table 2. Seed cotton yield and economics as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Seed cotton yield (kg/ha)	GMR (Rs/ha)	NMR (Rs/ha)	B:C ratio
Main plot : *Bt* cotton hybrids				
H_1: Mallika	2904	144710	89333	2.60
H_2: Ajeet 155	3302	164550	106790	2.85
H_3: MRC 7347	3199	159400	102260	2.79
SE+	66.54	3316	2154	0.04
CD (p=0.05)	260.80	12997	8444	0.15
Sub plot: Plant geometry				
G1 : Normal spacing (120 x 45 cm)	3032	151060	95843	2.73
G2 : Closer spacing (90 x 45 cm)	3239	161380	103080	2.76
SE+	59.53	2967	2067	0.04
CD (p=0.05)	205.69	10250	7143	N. S.
Sub-sub plot : Nutrient levels				
F_1: RD - NPK (100:50:50)	2932	147230	93017	2.71
F_2: 125 % RD – NPK	3141	156240	99482	2.75
F_3: 150 % RD – NPK	3332	165190	105880	2.78
SE+	73.67	3671	2458	0.04
CD (p=0.05)	214.71	10698	7163	N. S.
Interaction H x G				
SE+	103.11	5138	3581	0.06
CD (p=0.05)	N.S.	N. S.	12372	N. S.
Interaction H x F				
SE+	127.60	6358	4257	0.08
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
Interaction G x F				
SE+	104.19	5191	3476	0.06
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
Interaction H x G x F				
SE+	180.46	8992	6020	0.11
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
C.V. (%)	9.97	9.97	10.48	6.76
Grand mean	**3135**	**156220**	**99460**	**2.75**

spacing (120 x 45 cm). Although, significant variation in B:C ratio was not observed in respect to spacing.

Effect of nutrient levels : In comparison with recommended NPK level, effects of higher doses (125% and 150% NPK) were studied in *Bt* cotton hybrids. Application of 150 per cent NPK level produced taller plants (175.62 cm). It was significantly superior over 100 per cent NPK level for plant height (161.88 cm). The number of monopodial and sympodial branches/plant were found to highest in 150 per cent NPK level. The higher nutrient availability through graded levels of fertilizers might have increased number of levels and production of photosynthates which reflected in more number branches/plant. These observations are in conformity with Jadhav *et al.,* (2015). Application of nutrient level 150 per cent NPK recorded highest number of bolls/plant (44.44), boll weight (4.17 g), both resulting to increased yield per plant (164.02 g). Greater supplement of nutrients to the crop resulted in synthesis of higher photosynthates

Table 3. Interaction of *Bt* cotton hybrids x plant geometry for NMR (Rs/ha)

Bt cotton hybrids /	Plant geometry	
	G_1 : 120 x 45 cm	G_2 : 90 x 45 cm
H_1- Mallika	81,952	96,715
H_2- Ajeet 155	1,05,560	1,08,020
H_3- MRC 7347	1,00,010	1,04,500
SE+	3,581	
CD (p=0.05)	12,372	

which in turn helped to produce seed cotton yield/ plant. The result of seed cotton yield presented in Table 2 indicated that 150 per cent NPK level yielded significantly higher seed cotton yield (3332 kg/ha) over 100% NPK (2932 kg/ha). But it was statistically on par with 125 per cent NPK. Similar trend of seed cotton yield was also observed for gross and net monetary returns. The highest GMR (Rs 1,65,190/ha) was realized with

Table 4. Picking wise share of seed cotton and GOT (%) as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Picking wise share of seed cotton yield			GOT (%)
	First picking	Second picking	Third picking	
Main plot : *Bt* cotton hybrids				
H_1: Mallika	57.11 (35.01)	26.44 (15.36)	17.00 (9.81)	37.16
H_2: Ajeet 155	43.57 (25.95)	25.95 (15.10)	30.70 (17.97)	36.16
H_3: MRC 7347	60.92 (37.73)	21.93 (12.67)	17.14 (9.90)	35.11
SE+	1.42	0.81	1.15	0.25
CD (p=0.05)	5.56	N.S.	4.50	0.97
Sub-plot: Plant geometry				
G1: Normal spacing (120 x 45 cm)	53.27 (32.53)	25.77 (14.99)	21.14 (12.30)	36.24
G2: Closer spacing (90 x 45 cm)	54.46 (33.26)	23.77 (13.76)	22.10 ()12.82	36.05
SE+	0.94	0.71	0.80	0.36
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.
Sub-sub plot : Nutrient levels				
F_1: RD - NPK (100:50:50)	54.29 (33.08)	24.22 (14.05)	20.99 (12.21)	35.74
F_2: 125 (% RD) – NPK	53.78 (32.84)	25.72 (14.95)	21.45 (12.45)	36.10
F_3: 150 (% RD) – NPK	53.53 (32.76)	24.39 (14.12)	22.41 (13.03)	36.59
SE+	1.19	0.54	1.05	0.44
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.
Grand mean	**53.87 (32.89)**	**24.97 (14.38)**	**21.62 (12.56)**	**36.14**

*-Figures in parenthesis are Arcsin transformed values.

150 per cent NPK level, it was marginally higher (Rs 6,398/ha) over 125 per cent NPK. However, the nutrient levels were found statistically equal for B:C ratio.

Interaction of *Bt* cotton hybrids x spacing : The *Bt* cotton hybrid x spacing interaction was significant for net monetary returns (Table 3). The *Bt* hybrids Ajeet 155 and Dr. Brent were found to equally profitable in both the plant spacings. The hybrid Ajeet 155 *Bt* under closer spacing was the most remunerative interaction (Rs 1,08,020/ha). The interaction effects indicate that *Bt* cotton hybrid Mallika was significantly remunerative under closer spacing (90 x 45 cm) over normal spacing as compared to other hybrids for net monetary returns. This might be due to comparatively less competition resulting higher yield of Mallika *Bt* under closer spacing as compared to other hybrids.

Picking wise share of cotton : *Bt* cotton hybrids had distinct variation in picking wise share of seed cotton (Table 4). The hybrids Dr. Brent and Mallika had significantly higher share over Ajeet 155 at first picking showing their earliness. However, at third picking, Ajeet 155 *Bt*, had significantly more seed cotton yield share over rest of the two hybrids. This might be due to more boll retention at later stage in Ajeet 155 with availability of moisture received from late rains in the month of October and November. The plant geometry and nutrient levels had no significant impact on picking wise share of seed cotton.

Ginning outturn : The Mallika *Bt* hybrid recorded highest ginning outturn (37.06%) where as Dr. Brent had significantly lowest Ginning outturn (35.11%). Plant geometry and nutrient levels didn't affected GOT statistically (Table 4).

REFERENCES

Jadhav, S. G., Chavan, D. A., Gokhale, D. N. and Nayak, S. K. 2015. Influence of plant geometry, growth regulator and nutrient management on performance of *Bt* cotton under irrigated condition. *Int. J. Trop. Agric.* **33** : 1755-58.

Malavath, R., Naik, R., Pradeep, T. and Chuhan, S. 2014. Performance of *Bt* cotton hybrids to plant population and soil types under rainfed condition. *Agrotechnol.* **3** : 120. Doi:10.4172/2168-9881.1000120

Pendharkar, A. B., Solunke, S. S., Sawargaonkar, G. L. and Kote, G. M. 2010. Response of *Bt* cotton hybrids to different plant spacings under rainfed condition,. *Adv. Res. J. Crop Improv.*, **1** : 180-82.

Raghu Rami Reddy, P. and Gopinath, M. 2008. Influence of fertilizers and plant geometry on performance of *Bt* cotton hybrid. *J. Cotton Res.Dev.* **22** : 78-80.

Sree Rekha, M. and Predeep, T. 2012. Performance of *Bt* cotton hybrid (RCH 2) at different plant densities and scheduling of nitrogen under rainfed conditions. *Crop Res.* **44** : 182-85.

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Physiological assessment for drought tolerance in cotton *hirsutum* genotypes under rainfed conditions in vertisols

S. RATNA KUMARI, S. BHARATHI , V. CHENGA REDDY AND E. NARAYANA

Acharya NG Ranga Agricultural University, Andhra Pradesh. Regional Agricultural Research Station, Lam, Guntur -522 034

E-mail : ratnaks47@gmail.com

ABSTRACT : A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, during 2013-2014 *kharif* season in black cotton soils under rainfed conditions. in strip plot design with two irrigation levels as main treatments *viz*; rainfed and need based irrigation and twenty five cotton entries as sub treatments in two replications to screen the entries for drought tolerance in black cotton soils. The crop suffered due to low moisture stress during boll formation and boll development stages. Under rainfed conditions, the entries viz; BGII 802, CNH 14, L 765, L788, BHC 2413, CA 105, L761, L770, RHC 0717 and LRA 5166 recorded higher RWC, the entries viz; H 1454/12, SCS 793, BGII S 802, HAG 805, CSH 1111, L 765, IH 70, RHC 0717,H1465/12 and ARBH 2004 recorded higher specific leaf weight and the entries viz; L 761, GBHv 177, L 770, L 762, ARBH 2004, H1454/12 and IH 70 recorded higher SCMR values. The per cent reduction in seed cotton yield under rainfed conditions ranged from 11.49 to 49.36. The entries Viz; *viz;* IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBhv 177 recoded higher seed cotton yield under rainfed conditions and the higher seed cotton yield in these entries was associated with the drought tolerance parameters to drought with more than two contributing characters of drought.

Key words : Cotton, Drought, RWC, SLW, SCMR and Seed Cotton Yield

Cotton plays an important role in Indian agriculture, industrial development, employment generation and in improving national economy. Out of about 50 species of cotton in the world, only four have been domestically cultivated for cotton fibre. *Gossypium hirsutum* and *Gossypium barbadense* are the most commonly cultivated species of cotton in the world. *Gossypium hirsutum* is the most important agricultural cotton, accounting for more than 90 per cent of world fibre production. In India, the cultivated sp. *Gossypium hirsutum* is grown in an area of 126.55 lakh ha with a productivity of 537 kg/ha. In Andhra Pradesh, cotton is one of the most important commercial crops. Cotton is grown mainly under rainfed conditions in Andhra Pradesh. The unpredictable nature of rainfall and frequent dry spells cause wide fluctuations in yield from year to year. It is grown in all the three-agro climatic zones of Andhra Pradesh under different agro climatic conditions. Climate change affects the rainfed areas of Andhra Pradesh badly. Deficient rains causes reduction in seed cotton yield. High temperatures also hasten the development especially during the boll filling period, thus resulting in smaller bolls, lower yields and poor lint quality (Hodges et al. 1993). Due to these reasons, the ability of plants to tolerate drought conditions is crucial for agricultural production worldwide. A drought tolerant variety improves the cotton yield and thus a boon to farming community. Keeping all these points in view, the present study is taken up to identify the entries for drought tolerance.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, during kharif 2013-2014 season in black cotton soils under rainfed conditions. The experiment was laid out in a strip plot design with two irrigation levels as main treatments *viz*; rainfed and need based irrigation and twenty cotton entries as sub treatments in two replications to screen the entries for drought tolerance. The total rainfall during the period under study was 1045 mm in 56 rainy days. The crop suffered due to low moisture stress during boll formation and boll development stages. Five plants at random were selected in each plot and the number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant were recorded. Third and forth fully opened leaves were collected for estimating Relative water content (RWC), chlorophyll stability index (CSI), Specific leaf area SLA) and specific leaf weight (SLW). Leaf chlophyll content was estimated according to Hiscox and Israelstam (1979). The mean data of five plants were subjected to statistical analysis by adopting the standard procedures described by Panse and Suhkatme (1985).

RESULTS AND DISCUSSION

Physiological and bio-chemical parameters: The data on physiological parameters were presented in Table No. 1 Variability was noticed in drought tolerance parameters *viz;* Relative Water Content (RWC), Specific Leaf Weight (SLW), Chlorophyll Stability Index (CSI) and SPAD Chlorophyll Meter Reading (SCMR).

The Relative Water Content (RWC) is the measure of the amount of the water present in the leaf tissue and the treatment having higher RWC under stress conditions would be preferable to maintain water balance. In the present study, under rainfed condition, the entries viz; BGII 802, CNH 14, L 765, L788, BHC 2413, CA 105, L761, L770, RHC 0717 and LRA 5166 recorded higher RWC. The percent reduction in RWC under rainfed conditions ranged from 0.66 (CNH 14) to 22.67 (H 1462/12). Higher percent reduction in RWC under rainfed condition was recorded in BGII S H 1462/12, CSH 1111, GJHv 500 and LRA 5166 and lower per cent reduction was noticed in CNH 14(0.66), L 761(0.85), IH 70 (1.16), GSHv 162 (1.97), BGIIS 802 (2.58) and H 1454/12(2.76). Malik *et al.,* (2006) reported that higher RWC is positively correlated with boll weight and seed cotton yield in cotton. The entries Viz; CNH 14 (75.6%), BGII 802 (75.4%) and IH 70 (68%) not only recorded higher RWC under rainfed conditions, but also had shown less percent reduction compared to need based irrigated conditions indicating their drought tolerant ability under moisture stress conditions.

Higher specific leaf weight was recorded in the entries viz; H 1454/12, SCS 793, BGII S 802, HAG 805, CSH 1111, L 765, IH 70, RHC 0717, H1465/12 and ARBH 2004 under rainfed conditions. The percent reduction in specific leaf weight under rainfed conditions compared to need based irrigated conditions ranged from -13.04 to 4.92 indicating the increase in leaf thickness in some of the entries. The percent increase in SLW was higher in entries *viz* CA 105(13.04), L770 (12.77), L762 (9.43), L 761(9.26), H1454/12(9.52) and BHC 2413(5.88) indicates the ability for adaptation under moisture stress conditions.

The significant positive correlation between SCMR and chlorophyll density across genotypes under a range of drought stress conditions was reported in the study conducted by Arunyanark *et al.,* (2015) and they also demonstrated that the SCMR could be a rapid tool to assess the genotypic variation for leaf chlorophyll density in order to identify the drought tolerant genotypes.In the present study, higher SCMR values were recorded in the entries viz; L 761, GBHv 177, L 770, L 762, ARBH 2004, H1454/12 and IH 70 under rainfed conditions. The percent reduction in SCMR under rainfed conditions compared to need based irrigated conditions ranged from 1.75 (RHC 0717) to 15.23 (L 763). Less reduction under rainfed conditions was noticed in the entries *Viz* RHC 0717 (1.75%), ARBH 2004(2.52%), L 761(3.38%), IH 70 (3.33%) and BS 79 (4%). The entries *viz*; L761 (48.8), ARBH 2004 (42.6) and IH 70 (40.7) had not only recoded higher SCMR values, but also had shown less reduction under rainfed conditions compared to need based irrigated conditions indicating their inbuilt tolerance to moisture stress.

Yield and yield attributing characters: The data pertaining to the seed cotton yield and yield attributing characters are presented in Table 2. Significant variation was noticed among

Table 1. Screening of cotton entries for Physiological parameters related to drought tolerance at Regl.Agril.Res. Station, Lam, Guntur during 2012-2013

Name of the entry	RWC (%)			SLW (mg/cm$^{2)}$			SCMR		
	I_1	I_0	Per cent reduction	I_1	I_0	Per cent increase and decrease	I_1	I_0	Per cent reduction
1 GBhv 177	72.3	68.4.	5.39	6.1	5.9	-3.28	42.5	39.3	7.53
2 BGII S 802	77.4	75.4	2.58	6.7	6.8	1.49	34.9	31.9	8.60
3 LRA 5166	79.1	69.8	11.76	5.8	5.9	1.72	38.4	35.1	8.59
4 RHC 0717	75.9	69.8	8.04	6.7	6.4	-4.48	34.2	33.6	1.75
5 H1462/12	71.9	55.6	22.67	6.7	6.5	-2.99	43.2	39.6	8.33
6 SCS 793	70.2	64.6	7.98	6.8	6.9	1.47	43.5	41.3	5.06
7 ARBH 2004	73.4	69.4	5.45	5.8	6.0	3.45	43.7	42.6	2.52
8 L 770	72.9	69.0	5.35	4.7	5.3	12.77	50.4	45.8	9.13
9 L 762	69.9	65.6	6.15	5.3	5.8	9.43	46.7	43.9	6.00
10 L 761	70.2	69.6	0.85	5.4	5.9	9.26	50.3	48.6	3.38
11 GJhv 500	73.3	64.9	11.46	5.7	5.3	-7.02	39.4	35.6	9.64
12 CA 105	72.5	69.3	4.41	4.6	5.2	13.04	45.6	40.7	10.75
13 NDLH 1938	74.8	68.6	8.29	6.2	6.4	3.23	46.4	41.7	10.13
14 GSHv 162	65.9	64.6	1.97	6.1	6.4	4.92	54.1	46.1	14.79
15 BS 79	70.2	64.6	7.98	4.6	4.8	4.35	42.5	40.8	4.00
16 H 1454/12	68.9	67.0	2.76	6.3	6.9	9.52	46.4	41.7	10.13
17 L 765	75.9	70.6	6.98	6.4	6.6	3.12	39.2	35.6	9.18
18 L 788	74.8	69.7	6.82	5.3	5.5	3.77	41.8	38.7	7.42
19 BHC 2413	72.5	69.7	3.86	5.1	5.4	5.88	35.9	32.7	8.91
20 IH 70	68.8	68.0	1.16	6.8	6.7	-1.47	42.1	40.7	3.33
21 L 763	67.6	64.2	5.03	6.1	5.8	-4.92	39.4	33.4	15.23
22 HAG 805	68.4	65.1	4.82	6.8	6.7	-1.47	37.5	36.2	3.47
23 CSH 1111	75.8	58.8	22.43	6.5	6.5	0.00	38.6	34.3	11.14
24 PH 1075	69.5	66.1	4.89	5.8	5.9	1.72	41.4	37.8	8.70
25 CNH 14	76.1	75.6	0.66	5.3	5.5	3.77	41.6	38.6	7.21

Table 2. Screening cotton genotypes for seed cotton yield and yield parameters under rainfed conditions at Regl. Agrl. Res. Station, Lam, Guntur -34 during 2013-2014

Treatment	Boll/ plant	Boll weight (g)	Sympodia	Seed cotton yield (g/plant)	Seed cotton yield (kg/ha)
Vertical factor: Irrigation treatments					
I_1	27.81	3.851	21.47	103.56	1522
I_0	25.21	3.804	19.65	101.90	1449
Mean	**26.51**	**3.827**	**20.56**	**102.73**	**1485**
SEm	0.173	0.0304	0.28	0.36	15.79
C D (p=0.05)	0.500	0.10	0.84	1.06	46.54
Horizontal factor: Cotton entries					
GBhv 177	26.03	3.212	19.30	84.15	1304
BGII S 802	23.20	3.475	16.97	80.65	1165
LRA 5166	23.12	3.225	18.30	75.00	1332
RHC 0717	27.02	3.375	20.97	91.25	1406
H1462/12	31.12	3.950	22.63	123.75	1782
SCS 793	27.52	4.850	17.23	134.10	1208
ARBH 2004	27.70	4.775	21.45	133.83	1858
L 770	23.77	3.725	17.63	89.28	1104
L 762	32.95	3.225	22.13	107.02	1920
L 761	21.77	3.000	19.98	65.75	973
GJhv 500	24.53	3.325	18.05	81.90	1149
CA 105	27.20	4.150	20.63	113.78	1759
NDLH 1938	24.10	3.975	20.73	96.45	1131
GSHv 162	26.80	4.075	22.23	109.83	1434
BS -79	27.37	4.275	22.88	118.25	1787
H 1454/12	23.20	4.125	21.30	98.23	1469
L 765	21.35	4.000	23.55	85.93	1216
L 788	26.40	3.950	21.30	104.63	1596
BHC 2413	25.62	3.925	22.80	100.97	1523
IH 70	35.10	4.250	23.15	151.43	2122
L 763	26.95	3.175	21.38	86.90	1716
HAG 805	25.52	3.625	20.38	94.15	1375
CSH 1111	25.45	4.625	17.73	119.05	1426
PH 1075	26.60	3.375	20.30	91.25	1538
CNH 14	32.45	4.025	20.95	130.73	1744
Mean	**26.51**	**3.827**	**20.56**	**102.73**	**1486**
SEm +	2.49	0.069	0.286	9.57	174
C D @ 0.05	7.34	0.200	0.840	28.23	514.3
Interaction : Vertical x horizontal					
SEm +	1.169	0.089	1.562	5.79	96.44
C D (p=0.05)	NS	NS	NS	NS	NS
CV (%)	16.24	13.27	10.74	7.97	9.18

the different entries in recording number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant. Significantly higher seed cotton yield was recorded in IH 70 followed by L762 and ARBH 2004 and the higher yield in these entries were associated with higher sympodial number, boll number and boll weight. The entries Viz; ARBH

2004,L-762,CA 105,BS 79, H 1454/12, L-788, IH 70, L 763 and CNH 14 recorded higher seed cotton yield under need based irrigated conditions, whereas the entries *viz;* IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBHv 177 recoded higher seed cotton yield under rainfed conditions. The per cent reduction in seed cotton yield under rainfed conditions ranged from 11.49 to 49.36. The lowest seed cotton yield reduction was recorded in the entry GSHv 177 and the highest seed cotton yield reduction was noticed in CNH 14.

From the experimental results, it is inferred that the entries viz; IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBHv 177have shown good performance under rain fed conditions with their inbuilt tolerance to drought having more than two contributing characters of drought tolerance in addition to yield attributing characters.

REFERENCES

Arunyanark, A. , S. Jogov, N. Vorosoot, C. Akkaseang, T. Kesmala and A. Patanthai 2015. Stability of Rrelationship beteen chlorophyll density and soil plant analysis developed chlorophyll meter reading in peanut across different drough stress conditions. Science Alert (An open access publisher)

Hiscox, J.D and Israelstam, G.F.1979.A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany*.**57:** 1332-34.

Hodges HF, Whisler FD, Bridges SM, Reddy KR, Mc Kinion J M 1998. Simulation in crop management: GOSSYM/ COMAX. In: Peart RM, Curry AB (eds) Agricultural system modeling and simulation. Dekker, New York, pp 235– 81

Malik, T.A. Sana-Ullah Malik, S 2006..Genetic linkage studies of drought tolerant and agronomic traits in cotton. *Pakistan Journal Botany* : 1613-19

Panse V G and Sukhatme 1985. Statistical methods for Agricultural Workers, ICAR, New Delhi. p. 232

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Poly mulch as moisture conservation technique in ET based drip irrigated *Bt* cotton in vertisols of Andhra Pradesh

S. BHARATHI, S. RATNA KUMARI, A. N. VAMSI KRISHNA, V. CHENGA REDDY AND E. NARAYANA

Acharya N G Ranga Agricultural University, Regional Agricultural Research Station, Guntur – 522 034

E-mail: bharathi_says @yahoo.com

ABSTRACT : The field experiment conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif 2013*-2014 and 2014-2015 to study the response of *Bt* cotton to drip irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in randomized block design with eight treatments and three replications indicated that there was significant difference in growth, yield contributing characters and seed cotton yield with different treatments tested. The conducive growth environment and microclimate under polyethylene mulching with or without drip on growth components finally reflected in better assimilate partitioning to reproductive structures as evidenced from the production of 5 – 46.8 per cent enhancement in producing number of bolls per plant compared to rainfed thus contributing significantly to higher seed cotton yield under poly mulched ET drip irrigation ranging from 7.5 – 47 per cent compared to rainfed. Among the treatments 0.6 Epan + polymulching recorded significantly higher seed cotton yield with maximum water and nitrogen use efficiency.

Key words : Drip irrigation, poly mulch, water use efficiency

Cotton is one of the most important commercial crop in Andhra Pradesh. The cotton crop is very sensitive to moisture stress. Excess moisture in the initial growth stages and uncontrolled water stress at later stages may adversely affect the cotton yield. Cotton is mostly grown under rainfed situation and if water is available farmers irrigate the fields in flood method which leads to severe flower and boll drop. Being a wide spaced row crop, drip irrigation offers much scope in terms of enhancing cotton productivity for yield and water. Enhancement in cotton yield to the tune of 39 per cent due to scientific scheduling of irrigation through drip over conventional irrigation has been reported (Lomte and Kagde, 2009). The practice of mulching with polyethylene is well proved for complete control of evaporation and saving the precious water in agriculture besides other advantages like weed control and enhanced seed cotton yield to the tune of 1.9 fold in cotton (Nalayani *et al.*, 2009). Drip irrigation has been shown to increase crop water productivity of cotton by increasing yields and decreasing the amount of water used (Cetin and Bilgen, 2002). But, the information on scheduling of irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in *Bt.* cotton in vertisols is very much lacking and hence this study was under taken.

MATERIALS AND METHODS

The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif* 2013-2014 and 2014-2015 to study the response of *Bt* cotton to drip irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in randomized block design with eight treatments and three replications. The soil of the experimental site is clay loam in texture, slightly alkaline with pH 7.8, low in available organic carbon (0.38 %), low in available nitrogen (188 kg ha^{-1}), medium in available phosphorus (28 kg ha^{-1}) and high in available potassium (856 kg ha^{-1}). The treatments were T_1 Control, T_2 polymulching, T_3 drip irrigation at 0.4 E pan , T_4 drip irrigation at 0.4 E pan + poly mulch, T_5 drip irrigation at 0.6 E pan, T_6 drip irrigation at 0.6 E pan+ poly mulch, T_7 drip irrigation at 0.8 E pan and T_8 drip irrigation at 0.8 E pan + poly mulch. The material used for polymulching was of 30 micron thickness with silver colour top layer to reflect more solar radiation on the crops and black bottom layer to enhance the soil temperature. The polyethylene mulch sheet was spread over the drip lateral pipes carefully and the edges were sealed with soil without much air trapped inside. The sowing lines were marked on the polyethylene sheets using sowing rope with markings at required spacing (60cm plant to plant). The holes were made using a two inch GI pipe against the already spread and edges sealed poly mulch at 60 cm spacing followed by sowing of cotton seeds carefully in the sowing holes. The spacing followed was 100 cm X 60 cm. Irrigations were given as per the treatments. The volume of water to be given through drip was calculated using following the formula $V=E_p$ x K_p (0.7) x K_c x A Where, V + Volume of water to be given (liters) / dripper, E_p = Pan evaporation (mm), K_p = Pan co efficient (0.7), K_c = Crop co efficient which vary for different growth stages of crop as per FAO Irrigation water Management Training Manual No.3 (Brouwer and Heibloem, 1986). For cotton, the crop co-efficient (K_c) was 0.45 for initial stage (0-25 DAS), 0.75 for development stage (26-70 DAS), 1.15 for boll development stage (71-120 DAS) and 0.75 for maturity stage (121-harvest). The evaporation reading recorded from the class A open pan evaporimeter was considered as 100 percent Etc and after adjusting to pan factor (for Guntur, it is 0.7), crop coefficient, the volume of water to be given for 0.4 Epan, 0.6 Epan and 0.8 Epan had been calculated using the above formula and irrigation was given as per the treatments on alternate days.

During the season, the cotton crop received 549.6 and 541.4 mm rainfall in the first and second year of experimentation respectively. Growth and yield parameters like number of monopodia, number of sympodia, number of bolls per plant, boll weight, seed cotton yield, seed index, lint index, GOT (%) and fibre quality, water use efficiency and nitrogen use efficiency was calculated accordingly. The results of both the years of experimentation has shown the same trend and hence the data of two years were pooled and analysed using standard analysis of variance.

RESULTS AND DISCUSSION

The poly ethylene mulching promoted the growth of cotton Jadoo BG II hybrid as could be seen from plant height enhancement 17 to 39 cm, and increment in number of sympodia per plant to tune of 4.24 to 7.23 under drip system, polymulch + drip system than rainfed (control). This might be due to favourable micro climate under polyethylene mulching and drip with higher available soil moisture lesser weeds competition and other favourable growth environment (Chen and Yin, 1989, Nalayini *et al.*, 2009). The conducive growth environment and micro climate under polyethylene mulching with or without drip on growth components were finally reflected in better assimilate partitioning to reproductive structures as recorded from production of 10.1 to 38.2 per cent enhancement in bolls per plant than rainfed (control). Growth stimulating condition under polyethylene mulching and polymulch + drip system has resulted in significant enhancement in assimilates partitioning towards economic produce. Thus, contributing significantly to higher seed cotton yield ranging from 10.96 to 40.35 per cent higher yield than rainfed. Elias and Goldhamer (1991) have reported 39 per cent enhanced yield in California due to polymulching in cotton crop. The drip irrigation also enhanced the seed cotton yield ranging from 17.99- 29.84 per cent higher yield than rainfed (control). The polyethylene mulch + drip system at 0.6 Epan has recorded significantly higher seed cotton yield (Table 1). Lowest seed cotton yield was recorded in rainfed (control). Poly mulching recorded significantly superior seed cotton yield over control and was on par with 0.8 Epan +P. There was no significant variation in seed index, lint index and ginning out turn among the treatments. The water use efficiency is an important factor for gaining maximum returns from limited water resources. Polymulching recorded a complete control of loss of water due to evoparationand thereby recorded higher water use efficiency than rainfed (control). Among the treatments, 0.6 Epan + polymulching recorded the highest water use efficiency of 6.9 kg seed cotton/ha/mm of water than rainfed with 6.02 kg seed cotton/ha/ mm of water.

Table 1. Growth, yield attributes, seed cotton yield and water use efficiency of cotton as influenced by drip polymulching and drip with polymulchin

Treatments	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Boll wt. (g)	Seed index (g)	Lint index (g)	GOT (%)	Seed cotton yield (kg/ha)	Cons-umptive use (mm)	WUE (kg/ ha/ mm)	NUE (kg/ ha/ mm)
Control	136	1.93	18.615	60.72	4.04	9.72	4.87	33.32	3284	545.5	6.02	27.37
Polymulching (P)	158	2.2	22.865	66.83	4	9.945	5.275	34.61	3681	545.5	6.75	30.67
0.4 Epan	160	2.07	24.185	72.1	3.925	9.095	4.865	33.15	3875	632.3	6.20	32.29
0.4 Epan +P	153	1.73	23.25	74.765	4.01	9.75	4.9	33.42	4116	632.3	6.58	34.30
0.6 Epan	175	2.4	25.85	78.265	4.205	10.095	5.01	33.16	4264	675.7	6.39	35.70
0.6 Epan +P	160	2.53	25.185	83.9	4.11	9.22	4.615	33.28	4609	675.7	6.90	38.41
0.8 Epan	169	2.47	25.75	71.565	4.01	9.84	4.87	33.15	3979	719.1	5.64	33.15
0.8 Epan +P	160	2.73	23.85	66.885	3.94	9.86	4.935	33.28	3644	719.1	5.16	30.36
SEm +	7.05	0.265	1.085	1.555	0.09	12.25	0.235	0.605	104.03	-	-	-
CD (p=0.05)	21.49	NS	3.27	4.785	NS	NS	NS	NS	315	-	-	-

REFERENCES

Lomte, D. M and Kadge, N.V. 2009. Responce of hybrid cotton (*Gossypium hirsutum* L.) to different levels of drip irrigation on Vertisol. *J.Cotton Res.Dev.***23**: 100-03.

Nalayani, P., Anandham R., Sankaranarayanan K. And Rajendran T.P. 2009. Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum* L.) and maize (*Zea mays)* cropping system. *Ind. Jour.Agro.* **54**:409-14.

Cetin, O and Bilgen, L. 2002. Effects of irrigation methods on scheduling and yield of Cotton. Agric. *Water Manag.***54**: 1-15.

Brouwer, C. And Heibloem, M. 1986. Irrigation water needs. Irrigation water management. Training Manual No.3, FAO, Rome, Italy

Chen, Q.E. and Yin, J.S. 1989. Effects of plastic mulch on soil properties and cotton growth in saline-alkali soils. *Jour. Soil Sci.* (China) **20**: 1-3.

Elias, F and Goldhamer, D.A. 1991. Plastic mulch increases Cotton Yield, reduces need for preseason irrigation. *California Agriculture* **45**: 25-28.

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Effect of macro nutrients and liquid fertilizers on the growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) under irrigation

VINAYAK HOSAMANI., A.S. HALEPYATI, B.K. DESAI. AND B.G. KOPPALKAR,

Department of Agronomy, College of Agriculture, Raichur-584 104

Email:halepyati49@rediffmail.com

ABSTRACT : The field experiment was conducted at Research farm, College of Agriculture, Raichur on medium black soil during *kharif*, 2011 to study the effect of macro nutrients and liquid fertilizers on the growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) under irrigation. The experiment was laid out in split plot design with three replications. Application of three levels of macro nutrients (75, 100 and 125% RDF) was tried in main plots. Foliar spray of liquid fertilizers was allotted to the sub plots *viz.,* S_1: Control, S_2: Foliar application of nutroplus (2 ml/l of H_2O (N/ 11.96%, K/7.25%, Mg/ 2.90%, Ca/14.5% and B/0.15%), S_3: Foliar application of Bio 20 @ 3 ml/ l of H_2O (N/20%, P/20%, K/20%, Mg/1.5%, Fe/0.146%, Zn/0.0.73%, Cu/ 0.073%, Mn/0.073%, Bo/0.029%, Mo/0.0012% and Co/0.0012%), S_4 : Foliar application of 1 per cent $MgSO_{-4}$ (Mangala $MgSO_4$) + 0.5 per cent $ZnSO_4$ (Mahazinc) and S_5: Foliar application of 2 per cent KNO_3. The results revealed that application of 125 per cent RDF recorded the highest seed cotton yield (q /ha), total number of bolls harvested/plant, seed cotton yield/plant, leaf area (dm^2 /plant), leaf area index, dry matter production and its distribution, gross returns, net returns and B:C ratio.(19.25q /ha, 26.19, 106.92 g /plant, 103.26 dm^2 /plant, 1.91, 336.83 g /plant, Rs.79,718/-, Rs.56,740/- and 3.51, respectively). Among the liquid fertilizers, foliar spray of liquid fertilizer, Bio 20 @ 3 ml/1 recorded significantly higher seed cotton yield (18.10 q /ha), bolls harvested/plant (24.88), seed cotton yield/plant (100.66 g), leaf area (73.20 dm^2 /plant), leaf area index (1.35), dry matter production and its distribution (308.90 g/plant), gross returns (Rs 75,022 /ha), net returns (Rs 51,964 /ha).

Key words : Bio 20, liquid fertilizers, RDF

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre crops of India playing key role in Indian economy by contributing nearly 33 per cent of total foreign exchange earnings of India. In India cotton has an area of 10.19 m ha with a production of 35.6 m bales and productivity of 496 kg lint /ha during 2011-2012 as against an area of 5.88 m ha with a production of 3.04 m bales and productivity of 88 kg /ha in 1950-1951 as per Cotton Advisory Board during 2011-12. In Karnataka, cotton occupies an area of 5.40 lakh ha with a production of 14.0 lakh bales and with productivity of 434 kg lint/ha (CAB 2011). The Northern dry zone of the state (Zone 2 and 3) cover partly the Tungabhadra and Upper Krishna Command areas (TBP and UKP). In these regions, *Bt* cotton is intensively cultivated on black soil under irrigation. The area under this crop in these command areas has been increasing distinctly over the past half decade and occupying more than 1.5 lakh ha during 2009-2010. The average seed cotton yield is around 20 q /ha which is far less than actual potential yield. To meet these demands, the cotton production and productivity has to be increased considerably. The factors responsible for low productivity in Tungabhadra Project (TBP) area of Karnataka are mainly due to imbalanced use of fertilizers, deficiency of micronutrients and physiological disorders (shedding of floral parts like squares, flowers and bolls) and due to pests (cotton bollworms). In this direction, a detailed research on combined effect of macro nutrients and liquid fertilizers was undertaken to maximize the seed cotton yield.

MATERIALS AND METHODS

The field experiment was conducted during *kharif*, 2011 at Agricultural College Farm, Raichur situated in North Eastern Dry Zone (Zone-2) of Karnataka at 16^o 12' N latitude and 77^o 20' E longitude with an altitude of 389 meters above the mean sea level. The experiment was laid out in split plot design with RDF (75, 100 and 125 %) in main plots and liquid fertilizers {control, foliar application of nutroplus @ 2 ml/lit, foliar application of Bio 20 @ 3 ml/lit, foliar application of $MgSO_4$ (1%) + $ZnSO_4$ (0.5%) and Foliar application of KNO_3 (2%) in sub plots with three replications. In main plot treatments *i.e.,* half of the nitrogen dose, entire dose of phosphorus and potassium in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP) were applied as basal dose and remaining half of the nitrogen in the form of urea was top dressed in three equal splits at 50, 80 and 110 days after sowing in the ring formed 5 cm away from the plant. The sub plot treatments *i.e.,* foliar spray of liquid fertilizers were imposed at flowering (90 DAS), boll formation stage (110 DAS) and boll bursting (125 DAS) of the cotton crop. The experimental field was clayey (56.05 % clay) in texture with the available nitrogen (218.00 kg /ha), phosphorus (32.00kg /ha), potassium (180.67 kg /ha) and organic carbon content (0.60 %), respectively. Sowing was done by hand dibbling as per the treatments on 08-07-2011.

RESULTS AND DISCUSSION

Effect of fertilizer levels : Application of 125 per cent RDF produced significantly higher seed cotton yield (19.25 q /ha), seed cotton yield (106.92 g /plant), mean boll weight (4.13g), number of bolls/plant (26.19), leaf area per plant (103.26 dm/plant), leaf area index (1.91), gross returns (Rs 79,718 /ha), net returns (Rs 56,740 ha), benefit cost ratio (3.51), NPK uptake (107.81, 30.08 and 109.25 kg /ha). (Table 1 and 2) over 100 per cent RDF (17.04 q /ha, 94.86 g / plant,24.42 , 100.63 dm/plant , 1.86, Rs 70,505 / ha, Rs 48,723 /ha 3.24,103.00, 26.80 and 104.53 kg NPK /ha, respectively). Seed cotton yield is governed by several factors, which have a direct or indirect impact. The factors which have a direct influence on seed cotton yield are yield components *viz.,* bolls harvested/plant, good opened bolls/plant, mean boll weight, lint index, ginning percentage and growth parameters like dry matter production and its amassing into various plant parts (leaf, stem and reproductive parts) and leaf area have a direct influence on the seed cotton yield and inturn have their dependence on growth fluctuation Solunke *et al.,* (2009), Hallikeri and Halemani (2002). The climatic factors may have circumlocutory influence on the seed cotton yield. In the present investigation, all these growth and yield attributing characters increased significantly due to application of RDF and might have contributed for increased yield, which were noticed with the application of 125 per cent RDF (Table 1 and 2). These results are in orthodoxy with those of, Anup Das *et al.,* (2006), Basavanneppa *et al.,* (2009), Solanke *et al.,* (2000), Katkar *et al.* (2002) and Moola Ram and Giri (2006) due to application of higher level of RDF.

Table 1. Leaf area (dm/plant), LAI , boll weight (g), bolls/plant, seed cotton yield (g/plant) and seed cotton yield (q/ha) of *Bt* cotton as influenced by macro nutrients and liquid fertilizers

Treatments	Leaf area (dm/plant)	LAI	Boll weight (g)	Number of bolls/plant	Seed cotton yield (g/plant)	Seed cotton yield (q/ha)
Main plots						
F_1 RDF (75%)	98.51	1.84	3.74	20.68	76.90	13.82
F_2 RDF (100%)	100.63	1.86	3.89	24.42	94.86	17.04
F_3 RDF (125%)	103.26	1.91	4.13	26.19	106.92	19.25
Mean	**100.80**	**1.87**	**3.92**	**23.75**	**92.89**	**16.70**
S.Em±	0.22	0.009	0.01	0.08	1.32	0.15
C.D. (p=0.05)	0.63	0.027	0.03	0.24	3.73	0.42
Sub plots						
S_1 Control	96.90	1.79	3.75	22.85	85.64	15.20
S_2 Foliar spray nutroplus (2%)	100.66	1.87	3.85	23.40	90.40	16.34
S_3 F.S. Bio 20 (3%)	102.93	1.91	4.06	24.88	100.66	18.10
S_4 F.S. $MgSO_4$ (1%)+$ZnSO_4$ (0.05%)	101.56	1.89	3.95	23.50	92.45	16.64
S_5 F.S. KNO_3 (2%)	102.18	1.88	3.97	24.12	95.32	17.21
Mean	**100.80**	**1.87**	**3.92**	**23.75**	**90.89**	**16.70**
S.Em±	0.29	0.006	0.01	0.11	1.71	0.19
C.D. (p=0.05)	0.81	0.018	0.04	0.31	4.82	0.55
S at the same F level						
S.Em±	0.56	0.01	0.03	0.27	4.18	0.47
C.D. (p=0.05)	1.65	NS	NS	NS	NS	NS
F at the same or different S levels						
S.Em±	1.11	0.01	0.02	0.24	3.41	0.35
C.D. (p=0.05)	3.35	NS	NS	NS	NS	NS

DAS – Days after sowingNS – Non significant

Effect of liquid fertilizers : Foliar spray of Bio 20 @ 3 ml/lit produced significantly higher seed cotton yield per ha (18.10 q /ha) followed by 2 per cent KNO_3 (17.21 q /ha) and 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (16.64 q /ha), foliar application of nutroplus 2 ml/l (16.34q /ha) and 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (16.64 q / ha) recorded *on par* results. Foliar spray of Bio 20 @ 3 ml/lit produced higher seed cotton yield (100.66 g /plant) over control (85.64 g /plant). These were *on par* with the results obtained by the spray of 2 per cent KNO_3, 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ and nutroplus 2 ml/lit (95.32, 92.45 and 90.40 g /plant, respectively.). Higher boll weight (4.06g) was recorded by the application of Bio 20 @ 3 ml/l, which differed significantly with foliar spray of 2 per cent KNO_3 (3.97g) and 1 per cent$MgSO_4$+0.5 per cent $ZnSO_4$ (3.95g), foliar spray of nutroplus 2 ml/l (3.85g) and control (3.75g). Foliar application of Bio 20 @ 3 ml/lit produced significantly higher number of bolls per plant at harvest (24.88) when compared to other foliar sprays. Foliar application of Bio 20 @ 3 ml/ lit (102.93 dm2 /plant) recorded highest leaf area/plant. Significantly higher nitrogen uptake (110.80 kg/ha) was recorded with Bio 20 @ 3 ml/ l over control (93.36 kg/ha) which inturn was on par with 2 per cent KNO3 (106.14 kg/ha). Higher phosphorus uptake (30.16 kg/ha) was recorded with the foliar spray of Bio 20 @ 3 ml/ lit over control (22.67 kg/ha). Foliar spray of nutroplus 2 ml/l of H2O, 1 per cent MgSO4 + 0.5 per cent ZnSO4 and 2 per cent KNO3 recorded *on par* results (26.64, 26.87 and 27.45 kg/ha,

Table 2. Gross returns (Rs/ha), net returns (Rs./ha), BC ratio, nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) uptake of *Bt* cotton as influenced by macro nutrients and liquid fertilizers

Treatments	Gross returns (Rs/ha)	Net returns (Rs/ha)	BC ratio	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Main plots						
F_1 RDF (75%)	57,231	36,572	2.77	98.38	23.39	100.67
F_2 RDF (100%)	70,505	48,723	3.24	103.00	26.80	104.53
F_3 RDF (125%)	79,718	56,740	3.51	107.81	30.08	109.25
Mean	**69,151**	**47,345**	**3.17**	**103.06**	**26.75**	**104.81**
S.Em±	212.98	266.42	0.01	1.45	0.67	0.90
C.D. (p=0.05)	601.50	752.43	0.03	4.09	1.90	2.53
Sub plots						
S_1 Control	63,762	44,072	3.29	93.36	22.67	91.42
S_2 Foliar spray nutroplus (2%)	67,304	44,186	2.90	102.00	26.64	104.30
S_3 F.S. Bio 20 (3%)	75,022	51,964	3.25	110.80	30.16	112.25
S_4 F.S. $MgSO_4$ (1%)+$ZnSO_4$ (0.05%)	68,608	47,924	3.31	103.00	26.87	107.50
S_5 F.S. KNO_3 (2%)	71,064	48,578	3.16	106.14	27.45	108.63
Mean	**69,151**	**47,345**	**3.17**	**103.06**	**26.75**	**104.81**
S.Em±	274.96	343.95	0.01	1.87	0.87	1.16
C.D. (p=0.05)	776.53	971.38	0.03	5.28	2.46	3.27
S at the same F level						
S.Em±	673.50	842.50	0.03	4.58	2.13	2.84
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS
F at the same or different S levels						
S.Em±	399.86	635.03	0.01	2.71	1.53	2.33
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS

DAS – Days after sowingNS – Non significant

respectively). Significantly higher potassium uptake (112.25 kg/ha) was recorded with the foliar spray of Bio 20 @ 3 ml/l and lower uptake (91.42 kg/ha) without foliar spray of liquid fertilizers. The treatments 1 per cent MgSO4 + 0.5 per cent ZnSO4 and 2 per cent KNO3 recorded *on par* results (107.50 and 108.63 kg/ha, respectively). Significantly higher gross returns (Rs. 75,022 /ha) were obtained with the application of 3 ml/l Bio 20 when compared to other foliar sprays. While lower gross return (Rs. 63,762 /ha) was recorded in control. Foliar spray with Bio 20 @ 3 ml/l recorded higher net returns (Rs. 51,964 /ha) as compared to 2 per cent KNO_3 (Rs. 48,578 /ha), 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (47,924 /ha) and 2 ml/lit nutroplus (Rs. 44,186 /ha). With regard to Bc ratio, foliar spray of 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (3.31) and control (3.29) recorded *on par* results and differed significantly than Bio 20 @ 3 ml/l, 2 per cent KNO_3 and nutroplus 2 ml/lit (3.25, 3.16 and 2.90, respectively).). Liquid fertilizer Bio 20 contains both macro and micro nutrients *viz.,* N, P, K, Mg, Zn, Fe, Co, Cu, Bo, Mo, Mn, which helped in chlorophyll formation, photosynthesis and uptake of other nutrient and enabled the plant to absorb the required nutrients from the solution through leaf surface and met the demand of crops for nutrients at the later stage. All these growth and yield attributing characters increased significantly due to application Bio 20 and which might have contributed for increased yield.(Table 1 and 2).

REFERENCES

Anup Das, Prasad, M., Gautam, R.C. and Shivay, Y.S., 2006. Productivity of cotton (*Gossypium hirsutum* L.) as influenced by organic and inorganic sources of nitrogen. *Indian J. Agric. Sci.,* **76** : 354-57.

Basavanneppa, M. A., Aladakatti, Y. R., Biradar, D. P. and Nidagundi, J. M., 2009. Response of Bt cotton to foliar nutrition under irrigated condition. National Symposium on *"Bt-Cotton: Opportunities and Prospects"* Nov.17-19, 2009. p.73. *Cotton Advisory Board* (CAB), 2011.

Hallikeri, S.S. and Halemani, H.L., 2002. Effect of spacing and fertilization on *hirsutum* cotton variety sahana under irrigated conditions. *J. Cotton Res. Dev.*, **16**: 181-85.

Katkar, R.N., Turkhede, A.B., Solanke, V.M., Wankhade, S.T. and Sakhare, B.A., 2002. Effect of integrated nutrient management of organic manures and fertilizers on soil properties and yield of cotton. *J. Cotton Res. Dev.*, **16**: 89-92.

Moola Ram and Giri, A. N., 2006. Response of newly released cotton (*Gossypium hirsutum* L.) varieties to plant densities and fertilizer levels. *J. Cotton Res. Dev.*, **20**(1): 85-86.

Solanke, V.M., Wankhede, S.T., Turkhede, A.B., Katkar, R.N. and Malvi, S.D., 2000. Agronomic requirement of new *hirsutum* hybrids in relation to their plant densities and fertilizer levels. *PKV Res. J.,* **24**(1): 1-4.

Solunke, P.S., Thokale, J.G. and Borve, U.S., 2009. Influence of foliar feeding of different micronutrients on yield and economics of hybrid cotton. National Symp. *"Bt. Cotton – Opportunities and Prospects",* Nagpur, p. 70.

Efficacy of glyphosate and other herbicides in management of weeds in rainfed cotton (*Gosspium hirsutum* L.) under high density planting system

B. S. NAYAK, R. K. PATNAIK, N. MANDI AND S. SAHU
Odisha University of Agriculture and Technology, Regional Research and Technology Transfer Station, Bhawanipatna – 766 001
E-mail: bsnayak2007@rediffmail.com

Cotton crop is prone to severe weed competition during its slow initial growth stage. It is infested with grasses, sedges and broad leaf weeds under upland ecosystem during the rainy season. The yield reduction due to weed infestation could be to the tune of 60 per cent (Sadangi and Barik, 2007). The crop weed competition for moisture and nutrients aggravates under high density planting system (HDPS) under the rainfed cotton growing tracts of India. Manual weeding and intercultivation are difficult due to closure crop canopy, low soil moisture and at times incessant rainfall during vegetative stages under HDPS. It is common recommendation to apply pendimethalin as pre-emergence spray supplemented with two to three intercultivations (Prabhu *et al.,* 2010). Several workers evaluated the use of post emergence herbicides like pyrythiobac sodium (Rao, 2011), glyphosate (Prabhu *et al.*, 2011 and Rao, 2011), and quizalofop-p-ethyl (Prabhu *et al.*, 2011 and Rao, 2011) either alone or in combination. The primary mode of action of pendimethalin is to prevent plant cell division and elongation in susceptible species. Pyrithiobac sodium inhibits acetolactase synthase, a key enzyme in biosynthesis of branched chain amino acids. Quizalofop-p-ethyl inhibits acetyl CoA carboxylase, a key enzyme in biosynthesis of fatty acids. Glyphosate kills plants by inhibiting enol pyruvyl shikimate phosphate synthase a key enzyme necessary for the biosynthesis of aromatic amino acids like phenylalanine, tyrosine and tryptophane, auxins, phytoalexins, folic acids, lignin and many other secondary products. Thus an attempt has been made in this study for sequential application of pendimethalin and quizalofop-p-ethyl, tank mixing of pyrithiobac sodium and quizalofop-p-ethyl and post-emergence application of glyphosate at different doses having different modes of action along with one hoeing in order to achieve the most effective and economic method of weed management in cotton grown under HDPS.

MATERIALS AND METHODS

A field experiment was carried out at the research farm of the All India Coordinated Cotton Improvement Project located in the Regional Research and Technology Transfer Station, Bhawanipatna, Odisha University of Agriculture and Technology during *kharif,* 2014 to evaluate different weed management methods in cotton grown under HDPS. The trial was laid out in a randomized block design with three replications using 11 treatments as mentioned in Table 1. The soil of the experimental site was clay loam in texture, low in available N, medium in available P and K with pH of 7.3. The cotton cultivar Suraj was sown with a spacing of 60 x

10 cm. The crop was raised with all recommended package of practices other than the weed control measures which were under testing. Pendimethalin was applied as pre emergence (PRE) spray @ 1.0 kg ha^{-1} at one day after sowing (DAS). Post emergence (POE) application of pyrithiobac sodium @ 62.5 g/ha and quizalofop-p-ethyl @ 50 g/ha was made at 20 DAS and glyphosate @ 0.5 kg/ha, 0.75 kg/ha and 1.0 kg/ha was done at 40 DAS. All the herbicides were followed by one hoeing at 40 DAS except glyphosate and the weedy check. One hoeing was done at 20 DAS in the glyphosate treated plots. In the weed free treatment, three hoeing and weeding were carried out at 20, 40 and 60 DAS. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using the spray volume of 500 l/ha. Weed density and dry weight were recorded at 30, 60 and 90 DAS.

RESULTS AND DISCUSSION

Data presented in Table-1 showed that among all the weed management treatments weed free check recorded significantly the highest seed cotton yield (SCY), bolls/plant, bolls/m and boll weight. This was followed by one hoeing at 20 DAS + Glyphosate @ 1.0 kg/ha, one hoeing at 20 DAS + Glyphosate @ 0.75 kg/ha and one hoeing at 20 DAS + Glyphosate @ 0.50 kg/ha which were *at par*.

The weeds/m was significantly the lowest in weed free check at 30 DAS (44), 60 DAS (20) and 90 DAS (12.7). Among the herbicides, the lowest weeds/m^2 was observed with one hoeing at 20 DAS + Glyphosate @ 1.0 kg/ha at 30 DAS (131), 60 DAS (73) and 90 DAS (51) followed by T_8 and T_7. The weed density was the highest in weedy check plot. Weed population showed a decreasing trend from 30 DAS to 90 DAS in all the treatments.

The weed dry weight/m^{-2} was significantly the lowest in weed free check at 30 DAS (29.9 g), 60 DAS (14.4 g) and 90 DAS (9.5 g). Among the herbicides, the lowest weed dry weight/m^{-2} was observed with T_9 at 30 DAS (88.9 g), 60 DAS (52.3 g) and 90 DAS (38.8 g) followed by T_8 and T_7. The weed dry weight was the highest in weedy check plot. Weed dry weight showed a decreasing trend from 30 DAS to 90 DAS in all the treatments.

The weed control efficiency was significantly the highest in weed free check at 30 DAS (87.2 %), 60 DAS (93.1 %) and 90 DAS (95.2 %). Among the herbicides, the highest weed control efficiency was observed with T_9 at 30 DAS (62.2 %), 60 DAS (74.7 %) and 90 DAS (80.6 %) followed by T_8 and T_7.

CONCLUSION

Therefore, it may be concluded that the integrated method of one hoeing at 20 DAS + post-emergence application of Glyphosate @ 1.0 kg ha^{-1} as directed spray at 40 DAS was the most effective and economic method of weed control in rainfed cotton grown under high density planting system.

REFERENCES

Patel, J.G., Raj, V.C., Usadadiya, V.P., Parmar, R.R., Sutaria, C.M., Leva, R.L. and Kumar, V. 2011. Comparative efficiency and economic viability of herbicides for controlling weeds in *Bt* cotton (*Gossypium hirsutum L.*). Book of papers of *"World Cotton Research Conference-5,"* 7-11 November, 2011, Mumbai, India, pp: 396-98.

Prabhu, G., Halepyati, A.S. and Pujari, B.T. 2010. Weed management studies in *Bt* cotton (*Gossypium hirsutum*) under irrigated

Table 1. Characters influenced by different treatments

Treatments	SCY (kg/ha)	Bolls/ plant	Bolls/ m^2	Boll weight (g)	Weed density ($No,/m^2$)			Weed dry weight (g/ m^2)			Weed control efficiency (%)		
					30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T1- Pendimethalin @ 1.0 kg a.i/ha as Pre- emergence + one hoeing at 40 DAS	1436	3.0	62	2.4	272	214	192.7	184.7	153.8	144.5	21.3	25.5	27.5
T2- Quizalofopethyl @ 50 g a.i/ha 20 DAS + one hoeing at 40 DAS	1147	2.6	54	2.3	284	226	205.3	193.3	163.0	154.0	17.6	21.2	22.8
T3- Pyrithiobac Sodium @ 62.5g a.i/ha 20 DAS +one hoeing at 40 DAS	1476	3.4	71	2.4	247	189	168.3	168.2	136.3	126.3	28.5	34.2	36.9
T4- Pendimethalin 1.0kg a.i/ha + Quizalofopethyl 50g a.i/ha at 20 DAS + one hoeing at 40 DAS	1584	4.5	93	2.3	227	169	147.7	154.1	121.4	110.8	34.4	41.4	44.6
T5- Pendimethalin 1.0kg a.i/ha + Pyrithiobac Sodium @ 62.5g a.i/ha 20 DAS + one hoeing at 40 DAS	1632	4.6	97	2.6	211	153	132.3	143.7	110.4	99.3	38.7	46.5	50.1
T6- Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha at 20 DAS + one hoeing at 40 DAS	1544	4.3	89	2.3	258	200	178.7	175.2	143.8	134.0	25.5	30.6	33.0
T7-One hoeing at 20 DAS + Glyphosate @ 0.5kg a.i/ha as directed spray at 40 DAS	2605	5.1	107	2.8	202	144	122.7	137.1	103.4	92.0	41.5	49.8	53.7
T8- One hoeing at 20 DAS + Glyphosate @ 0.75kg a.i/ha as directed spray at 40 DAS	2632	5.4	113	2.9	179	121	100.3	121.9	87.4	75.3	48.1	57.8	62.4
T9- One hoeing at 20 DAS + Glyphosate @ 1.0 kg a.i/ha as directed spray at 40 DAS	2677	5.8	132	2.9	131	73	51.7	88.9	52.3	38.8	62.2	74.7	80.6
T10- Weed free check (manual weeding at 20, 40 and 60 DAS)	3013	6.6	167	3.1	44	20	12.7	29.9	14.4	9.5	87.2	93.1	95.2
T11-Weedy check	884	1.9	40	1.9	346	288	266.7	235.1	207.1	200.0	0	0	0
SEm +	164.4	0.22	4.67	0.13	6.74	6.49	6.51	4.58	4.68	4.87	1.81	2.21	2.34
CD (p=0.05)	465.21	0.67	14.02	0.38	20.21	19.49	19.50	13.74	14.04	14.62	5.44	6.58	6.97

conditions. Proceeding of XIX National Symposium on *"Resource Management Approach towards Livelihood Security"*, 2- 4 December, 2010, UAS, Bangalore, pp: 263.

Prabhu, G., Halepyati, A.S. and Pujari, B.T. and Desai, B.K. 2011. Integrated weed management in *Bt* cotton (*Gossypium hirsutum L.*) under irrigated conditions. *Karnataka J. Agric. Sci.* **24** : 529-30.

Rao, A.S. 2011. Evaluation of pyrithiobac alone and in combination with grassy herbicides on weed control in cotton. Book of papers of *"World Cotton Research Conference-5"*, 7-11 November, 2011, Mumbai, India, pp: 406-09.

Sadangi, P.K. and Barik, K.C. 2007. Effect of weed management practices on nutrient depletion by weeds, yield and economics in winter irrigated cotton (*Gossypium hirsutum*). *Indian J. Agron.* **52** : 172-75.

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Empowerment of women to mitigate drugery in cotton picking

KUSUM RANA AND VINITA JAIN

Directorate of Extension Education,CCS Haryana Agricultural University, Hisar - 125 004

Email: kusum.rana@gmail.com

Abstract Agriculture is the primary source of employment for most developing countries including India. Women in Haryana are involved in most of the agricultural operations viz. transplanting, weeding, harvesting, post-harvest activities picking and plucking. Hisar is a pre-dominantly cotton growing district. Cotton is known as 'White Gold' grown in 85000 ha. Cotton picking is the tedious job exclusively handled by women folk. The study was conducted in the month of October- November at cotton farms of nine villages viz., Kirtan, Ladwa, Kishangarh, Bhagana, Talwandi Rana, Tokas, Neolikalan, Umra and Sadalpur of Hisar districts compromising of 200 respondents. Schedule was developed to collect data on socio economic profile of the respondents. However, cot bag was further tested on all the 200 women for 1 hour of cotton picking activity with both existing and improved method. During experiment time and activity profile, work output and acceptability of the cot bag was assessed. They reported very severe pain in palm, wrist, fingers, neck and shoulders. To mitigate these problems cotton picking bag developed by CCSHAU, Hisar was recommended. The results revealed that by using conventional bag the rural women could pick upto 40 kg of cotton in 7hr and earned Rs 200/day but by using cotton picking bag they could pick 50 kg of cotton in 7 hr, thus, earning Rs 250/person/day. Adequate rest pauses coupled with training on use of proper body postures along with light exercises for back and shoulders need to be given during the work to delay the onset of fatigue and its recuperation.

Key words : Cot bag, cotton picking, msusculo-skeletal problems

Women are involved in most of the agricultural operations *viz.,* transplanting, weeding, harvesting, post harvest activities like-picking and plucking, while in other agricultural related activities, they share the work with men folk. Hisar is a pre dominantly cotton growing district. Cotton is known as 'White Gold' and plays an important role in the agriculture and industrial activities of the nation .Our economy is consistently influenced by cotton through its production and processing sectors, and by generating direct and indirect employment to more than 8 million people. In Haryana, the cotton area includes five major districts namely Sirsa, Fatehabad, Hisar, Jind and Bhiwani and constitute 90 per cent of the crop in the state. Cotton picking is the tedious job exclusively handled by women folk. In Haryana, average 6-7 hours are spent daily in cotton picking. These jobs involve considerable amount of drudgery. Drudgery is conceived as physical and mental strain, fatigue, monotony and hardship experienced by human beings. Traditionally, she uses a cloth sheet/ head cloth for collecting picked cotton by tying it in the form of bag on their shoulders and back. Cotton picking with existing method leads to drudgery of the woman and retards her working efficiency. During the activity, cotton gets collected at the bottom of bag forming a ball like structure which droops down at her back. This touches her lower thighs and popliteal area and causes hindrance while walking during the activity. To mitigate these problems, cotton picking bag developed by CCS

HAU, Hisar was recommended. It is made of cotton clothes and designed as per anthropometric measurements of women. Shaped pockets provided in front and below waist line make it user friendly. It reduces drudgery of women while picking cotton. Cushioned belts avoid strain on shoulder, hand and neck. The present study was planned with following specific objectives:-

OBJECTIVES

- Assessment of socio economic and work profile of women involved in picking cotton.
- Studying musculo skeletal discomforts perceived by women while performing activity.
- Ascertaining acceptability of cot bag for selected parameters.

MATERIALS AND METHODS

The study was conducted in the month of October- November at cotton farms of nine villages *viz.,* Kirtan, Ladwa, Kishangarh, Bhagana, Talwandi Rana, Tokas, Neolikalan, Umra and Sadalpur of Hisar districts compromising of 200 respondents. Schedule was developed to collect data on socio economic profile of the respondents. However, cot bag was further tested on all the 200 women for 1 hr of cotton picking activity with both existing and improved method. During experiment time and activity profile, work output and acceptability of the cot bag was assessed. Musculo-skeletal problems as perceived by women while picking cotton through traditional method and with the help of cot bag was measured through Human Body map (Corlette and Bishop, 1976). Five point scale ranging from very severe pain (5) to very mild pain (1) was used to quantify the stress on muscles used in work. Participatory Rural Appraisal (PRA) was conducted in these villages.

RESULTS AND DISCUSSIONS

Results pertaining to the study are presented under relevant headings as socio-economic profile of respondents, economic profile, acceptability parameters for cot bag, perception of women on health, work and drudgery reduction ability of cot bag etc.

Table 1. Socio personal profile of respondents n=200

Socio personal variables	Frequency	Percentage
Age		
Upto 20 years	25	12.50
20-40 years	160	80.00
Above 40 years	15	7.50
Education		
Illiterate	63	31.50
Upto primary	88	44.00
Upto high school	47	23.50
Graduate	2	01.00
Family Education Status		
Low	123	61.50
Medium	75	37.50
High	2	01.00
Marital Status		
Unmarried	37	18.50
Married	163	81.50
Family Type		
Nuclear	62	31.00
Joint	138	69.00
Family Size		
Up to 4 members	58	29.00
5-7 members	127	63.50
Above 7 members	15	7.50

Perusal of data in Table 1 reveals that overwhelming majority of respondent's falls in the age group of 20-40 years of age (80.00%) followed by those who were up to 20 years of age (12.50) and above 40 years of age (7.50). Majority was educated up to primary level (44.00%), however 31.50 were illiterate. Remaining were educated up to high school level (23.50) while small percentage (1.00) have got formal education up to graduate level. Majority of respondents were having a low family education status (61.50%) followed by those who were having medium level (37.50), while just one percent have high level of education. Mostly were married (81.50%), having a joint family system (69.00%) and a family size between 5-7 members (63.50 %).

Regarding Economic profile of the respondents, data in Table 2 indicates that agriculture was the main occupation for more than half of the respondents (60.00%) followed by one-third respondents (31.50%) who were engaged as labourers primarily in agriculture sector. Only few (1.00) were in govt. service. Monthly family income was above Rs 6,000/ for about 40 per cent of the respondents followed by 31.50 who had income below Rs 3,000 and 29 per cent were having monthly income between Rs 3,000-6,000.

Perusal of data in Table 3 indicates that output of cotton picking was found to be more with the help of cot bag than the existing traditional jholis that women were using for picking. The increase in the amount of the cotton picked was due to proper collection of cotton in the improved cot bag. Unlike the traditional jholi, cot bag is very well adjustable on the shoulder and head of the workers and does not interfere with the hand and body movements of the workers. Hence, it can be concluded that cot bag showed better work output than existing tradition al jholi.

Musculo skeletal discomfort : Fig. 1 shows the musculo skeletal discomfort of cotton pickers. As hands are mainly involved continuously in cotton picking so very severe pain was reported in fingers and palms (m.s. = 4.8 and 4.5, respectively) . Moreover, they get abrasions while plucking cotton pods from hard and pointed cotton shells. This was followed by severe discomfort in mid back (m.s. = 4.4) , wrists (m.s. = 4.1) and lower back (m.s.= 4.0) .

Fig 1. Magnitude of musculo-skelatal discomfort

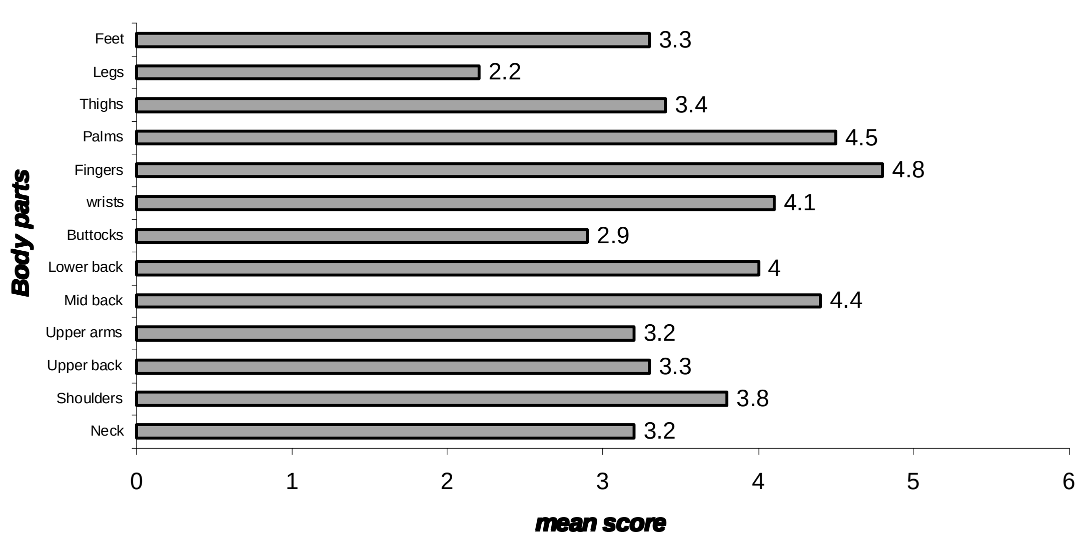

Table 2. Economic profile of respondents n=200

Economic variables	Frequency	Percentage
Occupations		
Agriculture	120	60.00
Private Sector	5	02.50
Govt. Service	2	01.00
Business	10	05.00
Labourer	63	31.50
Monthly Income		
Below Rs 3,000/month	63	31.50
Rs 3,000-6,000/month	58	29.00
Above Rs 6,000/month	79	39.50

Severe to moderate discomfort was reported in shoulders (m.s. = 3.8), thighs (m.s.= 3.4) and upper back and feet (m.s. = 3.3 each). During the activity, cotton gets collected at the bottom of bag forming a ball like structure which droops down at her back. This touches her lower thighs and popliteal area and causes hindrance while walking during the activity.This may be due to reason that that they used to stoop and change their posture 48 times for picking cotton pods from lower plants. Secondly, they used to bend to pick the cotton pods fallen on the ground while putting them in the pockets of bag at their back. For this they used to twist their hands and wrist putting stress on their shoulders too. Moreover, this stooping and bending was done while carrying weight of cotton pods in the bag hanged on their shoulders which they occasionally shifted at their head to relieve their shoulders for time being.

Table 3. Increase in cotton picking/day by cotton picking bag n=200

Cotton picking per day	Traditional Method		Cotton picking bag	
	Frequency	Percentage	Frequency	Percentage
Upto 20 Kg.	18	09.00	5	02.50
20-40 Kg.	170	85.00	87	43.50
40 Kg. & above	12	6.00	108	54.00

Data in Table 4 reveals that majority of women were highly relieved (60%) and relieved (37.50%) by using cot bag. Two third (71.50%) indicated that there work output was highly improved. It was considered highly acceptable and acceptable (64 and 36% respectively) by respondents. On field acceptability of cot bag, it was perceived to be highly acceptable by majority of women (59%). Data further indicate that overwhelming majority perceived reduction in pain in shoulder (92%), followed by neck and head (68%) and legs & thighs (50%). Regarding improvement in work efficiency, 98 percent reported picking more by using cot bag in comparison to traditional jholi. About fifty percent (48%) feel less fatigue on using cot bag, reducing back pain (53%) and less pain in hands (27%). Cot bag helped in reducing the drudgery of a women to a considerable extent as cot bag is evenly distributed over shoulder to hip region which helps the workers to maintain straight back without undue pressure on shoulders and lower back. Further workers were able to pick approximately 10 kg cotton more with cotton picking bag in 7 hours and thus earning Rs 250/ day in comparison to traditional method of cotton picking where they were plucking approximately 40 kg cotton in 7 hr earning Rs 200/day. Therefore, it is important to introduce training programmes in villages to promote usage of cot bag not only to reduce drudgery of women but to enhance earning capacity and ultimately raising standard of living of farm families.

Table 4. Acceptability parameters for Cot Bag n=200

Parameters	Frequency	Percentage	
Biomechanical Stress			
	No relief	-	-
	Moderate relief	5	02.50
	Relieved	75	37.50
	Highly relieved	120	60.00
Work Output			
	No improvement	-	-
	Moderate relief	10	05.00
	Improved	47	23.50
	Highly improved	143	71.50
Tool Factor			
	Not acceptable	-	-
	Needs modification	-	-
	Acceptable	72	36.00
	Highly acceptable	128	64.00
Field Acceptability			
	Not acceptable	-	-
	Needs persuasion	-	-
	Acceptable	82	41.00
	Highly acceptable	118	59.00
Health Related Parameters			
	Reduce pain in shoulder	184	92.00
	Reduce pain in neck & hand	136	68.00
	Reduce pain in legs & thighs	100	50.00
Work Efficiency Related			
	Increase work efficiency	50	25.00
	Pick more cotton as compared to conventional bag	196	98.00
Drudgery Reduction Related			
	Less fatigue as compared to conventional bag	96	48.00
	Reducing backache	106	53.00
	Less pain in hands	54	27.00

CONCLUSIONS

Summarizing, cotton picking is primarily women's responsibility in most part of India especially in Haryana. On an average women spends 6-7 hr in picking cotton collecting 25-30 kg of cotton/day during harvesting season. Cotton picking with existing method of using traditional jholi results in various musculo skeletal problems for the women. Output of cotton picking was found to be more with the help of cot bag. Majority found it to be highly acceptable. Overwhelming majority (92%) perceived that using cot bag reduced pain in their shoulders, backache (53%) and pain in hands (27%) and overall helped in reducing the drudgery of a women to a considerable extent as cot bag is evenly distributed over shoulder to hip region which helps the workers to maintain straight back without undue pressure on shoulders and lower back. Further workers were able to pick approximately 10 kg cotton more with cotton picking bag in 7 hr and thus earning Rs 250/day in comparison to traditional method of cotton picking where they were picking approximately 40 kg cotton in 7 hr and earning Rs 200/day. Therefore, it is important to introduce training programmes in villages to promote usage of cot bag not only to reduce drudgery of women, but enhance earning capacity and ultimately raising standard of living of families.

REFERENCES

Corlette, E.N. and Bishop, R.P. 1988. 'A technique for assessing postural discomfort, Ergonomics **19 :** 175-80.

Durnin J., Rahaman M. 1967. The assessment of amount of fat in the human body from measurements of skinfold thickness. *British Jour. Nutrition*, **21 :** 681-88

Garrow J S. 1981. Treat obsesity seriously. A clinical Manual. Edibug Churchill, Livingstone

Oberoi K., Singh S. 2007. Methodologies for assessment of ergonomic cost of work in book on Ergonomic Interventions for Health and Productivity by Suman Singh, Himanshu Publications, New Delhi, 40-66

Varghese, M.A., Saha, P.N. and Atreya, N. 1994. A rapid appraisal of occupational workload from a modified scale of perceived exertion, *Ergonomics* **37 :** 485-91.

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Staple length composition of production and export of cotton in India

DEVENDRA BEERALADINNI, H. LOKESHA AND SURESH S. PATIL

Department of Agricultural Economics, College of Agriculture, University of Agricultural Sciences, Raichur-584 104

E-mail: beeraladinnidevendra1975@gmail.com

ABSTRACT : India's raw cotton production and export witnessed a substantial increase over the years still not self sufficient in its total domestic requirement of different staple length group cotton for its flourishing textile industry. Hence, the study attempts to quantify the **c**omposition of Indian raw cotton production and exports by staple length. The time series data on area, production and export of raw cotton from India for the period 1996-1997 to 2013-2014 was elicited from the websites of Ministry of Commerce and Industry, Government of India (www.commerce.nic.in) and Cotton Corporation of India Ltd., During the last 18 years the production of long staple cotton has increased (12.32 per cent/annum) while the production of short staple cotton has decreased (6.78%/annum) and that of Extra Long Staple (ELS) cotton remained constant around 5 lakh bales annually. This has witnessed a paradigm shift in export of staple length composition of raw cotton from India. The percentage share of short staple cotton in total raw cotton exports has declined from 92.25 to a mere 1.21 per cent for the period from 2002-2002 to 2013-2014. While the percentage share of long staple cotton in total raw cotton export has increased from 6.79 to 95.50 per cent during the same period. But there was no much change in the export share of ELS cotton. However during the same period, the export share of ELS cotton was increased from nil to a mere 1.87 per cent except a share of more than 10 per cent during 2005-2006 to 2008-2009. At present more than 90 per cent of cotton area covered under *Bt* hybrids in India, inadvertently it has led to a surplus production of long staple cotton *i.e.,* 87 per cent against the requirement of 32-35 per cent. In case of short staple and ELS cotton the production is less than the requirement. Hence, India imports ELS and short staple cotton from other countries. During 2013-2014, India imported 10.47 lakh bales of short staple and ELS cotton and exported 105 lakh bales of long staple cotton which constituted 95.80 per cent of total raw cotton exports. Therefore to encourage the production of short staple and ELS cotton in India research efforts should be made to develop *Bt* hybrids (as in long staple cotton) in these fibre length classes.

Key words : *Bt* hybrids, ELS, export share, production, raw cotton, staple length, TPM

Cotton is an important fibre crop of India which plays a vital role in the country's economy by meeting the domestic textile industry requirements and export demand. Its contribution is significant in terms of enhanced farm income, employment and export earnings. As per the estimate of FAO, India is one among the major players in raw cotton exports and its share of world exports of cotton expected to increase 20 per cent by 2023. Cotton exports among agricultural commodities play a vital role in India's total exports valued at Rs. 21676.33 crores during 2013-2014 which was declined to Rs.11314.82 crores during 2014-2015. Cotton is one among the top five agricultural commodities exported from India and accounts for 59 per cent of the raw material consumption in textile industry (WWF report, 2012).

India is unique among the major cotton producing countries because a broad range of agro climatic and soil conditions permits cultivation of all varieties and different staple length of cotton. India has been the traditional producer and exporter of short staple cotton (Bengal *desi*) it was reported that till the end of the 1960's, longer staple cotton was imported while the surplus short staple cotton was exported (World Bank, 1999). During 1980's India was a leading exporter of extra long staple (ELS) cotton (DCH 32) and has been emerged as a regular exporter of long staple (LS) cotton after the introduction of *Bt* cotton in 2002-2003. As the staple composition of cotton production in India has changed significantly the relative share of different staple group of cotton in total raw cotton export was also changed. India's cotton production witnessed a substantial increase over the years. But the production of ELS and short staple cotton is shrinking and we are importing the same from other countries. Hence, the study attempts to quantify the composition of Indian raw cotton production and exports by different class of staple length.

MATERIALS AND METHODS

The study is based on the secondary data on production and export (value and quantity terms) of raw cotton (HS Code: 520100; COTTON, NOT CARDED OR COMBED) from India for the period 1996-1997 to 2013-2014, was elicited from the websites of Ministry of Commerce and industry (www.commerce.nic.in), Food and Agriculture Organization (www.faostat.fao.org) and Cotton Corporation of India Ltd., (www.cot**corp**.gov.in). Export of five different staple length class raw cotton from India *viz.,* Short staple (below 20.50mm), Medium (20.50 to 24.50mm), Medium long (24.50 to 28.00mm), Long staple (28.5 to 34.50mm) and Extra Long staple (34.50 and above) cotton were considered for the analysis.

Growth rates in production and export of raw cotton by staple length : The following functional farm was used to estimate the growth in production and export of raw cotton by staple length in quantity terms

$Y_t = Y_o (1 + r)^t$ .... (1)

Transforming this to logarithmic farm

$\ln Y_t = \ln Y_o + t \ln (1 + r)$ .... (2)

Where ;

Y_t = Quantity of cotton export/production

r = Compound Annual Growth Rate (CAGR)

ln = Natural Logarithm

If $\ln Y_o = \hat{a}_1$ and $\ln (1 + r) = \hat{a}_2$, then the equation (2) becomes

$\ln Y_t = \hat{a}_1 + \hat{a}_2 t$.................................. (3)

β_1 and β_2 are estimated by Ordinary Least Square (OLS) technique and CAGR is estimated by, r = (antilog β_2 -1) * 100

Shifts among the staple length groups : The shifts and retention percentage in export among the different staple length groups of cotton in India over a period of time were analysed by employing the first order Markov chain model. Markov chain analysis is an extension of probability theory developed by A.A.Markov in 1907 (Sujatha *et al.,* 2007). This econometric analysis helps us to know the shift of export share among the different staple length classes of cotton from one period to another over a period of time. The estimation of transitional probability matrix (P) is central to this analysis. The transition probability matrix (TPM) is a rectangular array would summarize the transition probabilities for a given Markov process.

$$P = \begin{matrix} P00 & P01 & P02 & \ldots & \ldots \\ P10 & P11 & P12 & \ldots & \ldots \\ P20 & P21 & P23 & \ldots & \ldots \end{matrix}$$

The Matrix P is called probability matrix. The probabilities P_{ij} must satisfy

$0 \leq P_{ij} \leq 1$ and $\Sigma P_{ij} = 1$ for I = 1, 2.........N

The elements P_{ij} of the matrix P indicates the probability that export will switch from staple length class i to staple length class j with the passage of time. In other words the matrix explains the switching behavior of cotton export in India among the different staple length group over a period of time indicating the direction of change in export share of these groups. The row elements in the transitional probability matrix imply the probability of retention (Diagonal element of the row) of export share by the corresponding group and extent of loss in export share (other than diagonal element of the row) on account of competing groups. The column elements indicate the probability of retention in export share and gain by the respective group from the other staple length group. An examination of the diagonal elements indicates the retention of export share in its favour. The proportionate changes in export share of different classes of cotton from year to year are as a result of the factors like weather, technology, price and institutional changes. Therefore it can be assumed that the combined influence of these individual forces indicates a stochastic process. In the present context, the export of different staple length class of cotton is considered to be a random variable which depends only on the past exports, which can be denoted algebraically as r

$$E_{jt} = \sum_{i=1}^{r} E_{jt-1} * P_{ij} + e_{jt} \text{ ....} (4)$$

Where,

E_{jt} = Export of the j^{th} staple group during the year t.

E_{jt-1} = Export of the j^{th} staple group during the period t-1.

P_{ij} = probability that the exports will shift from i^{th} staple group to j^{th} staple group.

e_{jt} = error term which is statistically independent of E_{jt-1}.

t = number of years considered for the analysis

r = number of staple length groups included in the model

The transition probabilities of the Markov chain model were estimated by Minimum Absolute Deviations (MAD) estimation procedure, which minimizes the sum of absolute deviations. The conventional linear programming technique was used, as this satisfies the properties of transitional probabilities of non negativity restrictions and row sum constraints in estimation. The linear programming formulation was stated as

Min O P* + I_e

Subject to, X P* + V = Y

G P * = 1

P * ³ O

Where,

P* is a vector in which probability P_{ij} are arranged; O is a null vector; I is an appropriately dimensioned vector of areas; e is the vector of absolute error (| U |); Y is the vector of export of each staple length group; X is a block diagonal matrix of lagged values of Y; V is the vector of errors; and G is a grouping matrix to add the row elements of P arranged in P* to unity. These P* vectors were arranged to obtain the transitional probability matrix which indicates the overall structure of the transitions that had taken place in the system.

RESULTS AND DISCUSSION

CAGR of production and export of raw cotton in India by staple length : Compound annual growth rates (CAGR) for production and export of different staple length group were analysed for a period of eighteen years *i.e.,* from 1996-1997 to 2013-2014. The production of short staple (-6.78%) and medium staple (-5.13%) cotton exhibited a negative growth whereas medium long (4.54%), long staple (12.32%) and ELS (0.11%) exhibited a positive growth. In over all the production of raw cotton was increased at 7.98 per cent/annum (Table. 1). There was a significant increase in production of long staple cotton mainly attributed to introduction of Bt-cotton. Growth in export quantity of different staple length group of cotton revealed that medium (-3.15%) and ELS cotton (-0.03 %) exhibited a negative export growth whereas short staple (1.05%), medium long (54.85%) and long staple cotton (105.64%) exhibited a positive export growth. In overall the export of raw cotton was increasing at 34.85 per cent/annum in quantity terms. The increase in export of medium long and long staple cotton was on account of improvement in yields during the current decade. It was reported that over the past 35 years, the average growth of cotton production in India has been 4.6 per cent. However, since 2000, cotton production in India has been growing rapidly 11.6 per cent annually. The surge in cotton production in India is mainly due to the introduction of *Bt (Bascillus thuringiensis)* cotton in 2002 (Caesar B.Cororaton,2008).

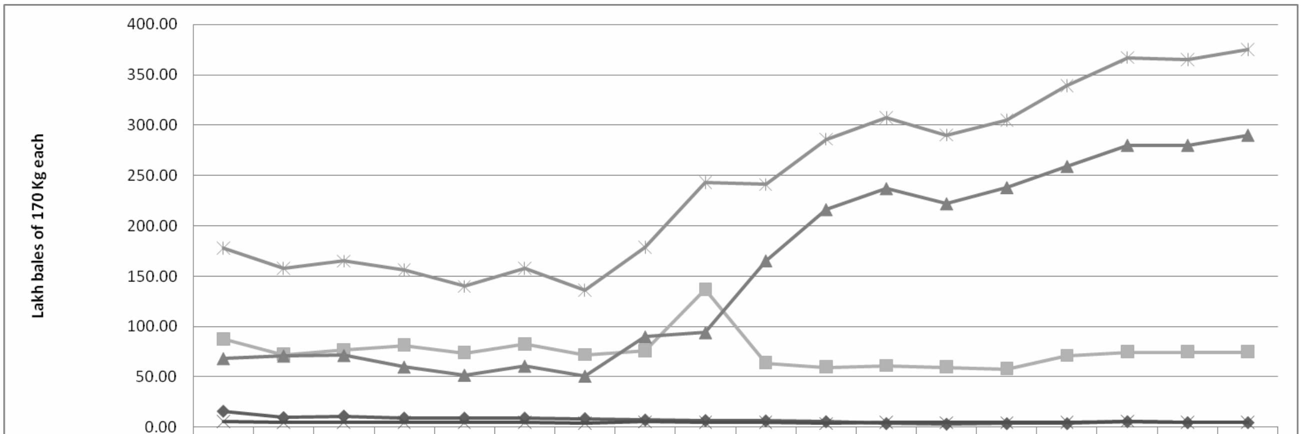
Table 1. CAGR of production and export of raw cotton in India by staple length group (1996-1997 to 2013-2014)

Particulars	CAGR (%)	
	Production	Export
Short staple (below 20.5 mm)	-6.78**	1.05^{NS}
Medium (20.5 to 24.5 mm)	-5.13*	-3.15*
Medium long staple (24.5 to 28 mm)	4.54^{NS}	54.85**
Long staple (28.5 to 34.5 mm)	12.32**	105.64**
Extra Long Staple (34.5 and above)	0.11^{NS}	-0.03^{NS}
Overall	**7.98****	**34.85****

* Significant at 5% ** Significant at 1 %
NS-Non Significant
Note: Short staple also includes Bengal *deshi* cotton.

Staple length composition of Indian raw cotton in production and export : During the last 18 years output of long staple cotton grew rapidly increasing by 12.32 per cent annually. In contrast the production of short staple cotton dropped drastically decreased by 6.78 per cent annually. Whereas the production of ELS cotton remained constant around 5 lakh bales annually (Fig.1). As a result of this in 2001-2002, export share of the short staple cotton in total raw cotton exports was more than 92 per cent and that of medium staple cotton was about 7 per cent whereas there was no export of medium long and long staple cotton (Fig.2). The export of long staple cotton started slowly picking up only after 2002. The export share of long staple cotton which was just about 5 per cent in 2002-2003 increased to more than 95 per cent in 2013-2014 and at the same time the export share of short staple cotton decreased to a mere 1 per cent in 2013-2014 which was more than 92 per cent during 2001-2002. While export of ELS cotton was picked up from 2003-2004 and increased to 17.45 per cent in 2007-2008 thereafter started decreasing and its share touched a lowest 0.42 per cent during 2012-2013. This is attributed to the fact that *Bt* cotton varieties are medium long and long staple varieties.

The wider adoption of *Bt* hybrids poses



	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Short Staple	16.25	10.00	11.50	9.50	9.50	9.50	9.00	7.60	7.11	6.80	6.00	4.00	3.50	4.00	4.00	6.00	5.00	5.00
Medium Long	87.54	72.50	77.00	81.50	74.00	82.50	72.00	75.90	136.80	64.00	60.00	61.00	60.00	58.00	71.00	75.00	75.00	75.00
Long Staple	68.45	71.00	71.50	60.00	52.00	61.00	51.00	89.95	94.07	165.40	216.15	237.00	222.00	238.00	259.00	280.00	280.00	290.00
Extra Long Staple	5.66	4.50	5.00	5.00	4.50	5.00	4.00	5.50	5.02	4.80	3.85	5.00	4.50	4.50	5.00	6.00	5.00	5.00
Total	177.90	158.00	165.00	156.00	140.00	158.00	136.00	178.95	243.00	241.00	286.00	307.00	290.00	304.50	339.00	367.00	365.00	375.00

Fig 1. Cotton production in India by staple length during 1996-1997 to 2013-2014

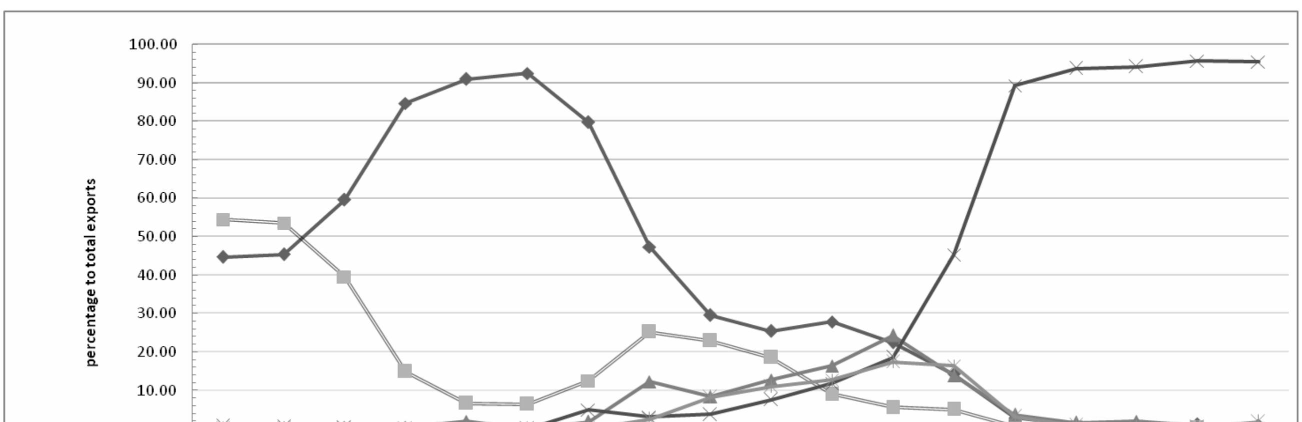
production and utilization problems as Bt cotton was developed in hybrids with trait for medium and long staples. Thus, with more than 90 per cent of cotton area in India coming under *Bt* hybrids, inadvertently it has led to a surplus production of medium long and long staple cotton more than what India can consume (87 % against 32-35%). Simultaneously, there is a reduction in the production of short staple cotton, a trait of desi against the requirement of 10-15 per cent (Ramasundaram *et al.,* 2011). The current production of ELS cotton in the country is only around 5 lakh bales against the requirement of 7 lakh bales. This indicates that India is not self sufficient in its total domestic requirement of different staple length group cotton for its flourishing textile industry. In case of short staple and extra long staple (ELS) cotton Indian production is less than the requirement hence it imports ELS and short staple cotton from other countries. India's production of ELS cotton is far below the local requirements of the textile mills (Cotton Exports Guide, 2007). India during 2013-2014 imported 10.47 lakh bales of short staple and ELS cotton to meet requirements of its domestic textile industry (Commodity profile - cotton, 2015). It was reported that the fibre quality and yield of ELS varieties have deteriorated in recent years causing marketing problems and lower returns

Table 2. Transitional probability matrix of Indian raw cotton exports: Period I (1996-1997 to 2002-2003)

Staple length group	Short staple	Medium	Medium Long	Long Staple	ELS	Others
Short staple	**0.9738**	0.0173	0.0050	0.0039	0.0000	0.0000
Medium	0.2726	**0.7240**	0.0000	0.0034	0.0000	0.0000
Medium long	0.8624	0.0000	**0.0000**	0.0000	0.0000	0.1376
Long staple	1.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000
ELS	1.0000	0.0000	0.0000	0.0000	**0.0000**	0.0000
Others	0.0000	0.0000	0.0000	1.0000	0.0000	**0.0000**

to growers therefore farmers are increasingly shifting to long staple varieties which have higher yields and fewer quality problems (Dhruv Sood, 2014). Where as in case of medium and long staple cotton Indian production exceeds the requirement and thus have exportable surplus in these groups. The country had exported 105 lakh bales of long staple cotton in 2013-2014 which constituted 95.47 per cent of total raw cotton exports from India.

Shifts in production and export among different staple length group or raw cotton : The transitional probability matrix was obtained to find out the retention of export share of different staple length group cotton in two periods *i.e.,* period I (1996-1997 to 2002-2003) and period II (2003-2004 to 2013-2014). Rows of the TPM indicate the export share of corresponding group lost to the other group. On the other hand columns indicate export share gained by the respective group and diagonal elements of the TPM reflects retention of export share by each group. During the period I, short staple cotton retained 97.38 per cent of export share in total raw cotton export from India and medium staple cotton retained 72.40 per cent (Table. 2). While medium long, long staple and ELS cotton have exhibited zero retention of export share in total raw cotton export. Short staple cotton which retained more than 97 per cent of its share in total raw cotton exports from India during first period did not retained much of its share in the second period. Short staple retained 54 per cent and medium short staple retained a mere 5 per cent of export share compared to first period. On the other hand medium long and long staple group which exhibited zero retention during first period retained more than 99.28 per cent and 37.99 per cent of export share respectively in total raw cotton exports during the period II (Table 3). Hence the TPM revealed that during the period I short staple and medium staple cotton dominated the total raw cotton export of India. While, during the period II medium long and long staple cotton dominated the total raw



	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Short Staple	44.69	45.43	59.62	84.67	91.00	92.48	79.77	47.32	29.60	25.49	27.87	22.44	14.25	2.85	1.05	0.61	1.11	1.05
Medium Short	54.40	53.57	39.57	14.87	6.68	6.41	12.48	25.26	22.93	18.53	9.01	5.58	5.02	0.67	0.22	0.38	0.19	0.16
Medium Long	0.14	0.35	0.21	0.30	1.93	0.00	1.81	12.31	8.36	12.76	16.45	24.36	13.85	3.71	1.58	2.00	0.82	0.33
Long Staple	0.67	0.45	0.60	0.15	0.38	0.00	4.98	3.10	3.73	7.61	11.86	18.56	45.27	89.29	93.76	94.19	95.69	95.47
Extra Long Staple	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.49	8.25	10.96	12.76	17.45	16.36	3.19	0.94	0.46	0.42	1.87

Fig. 2. Staple wise raw cotton exports (% to total raw cotton exports) from India (1996-1997 to 2013-2014)

Table 3. Transitional probability matrix of Indian raw cotton exports: Period II (2003-2004 to 2013-2014)

Staple length group	Short staple	Medium	Medium long	Long staple	ELS	Others
Short staple	**0.5425**	0.3822	0.0000	0.0000	0.0000	0.0754
Medium	0.0358	**0.0537**	0.0000	0.0000	0.0000	0.9105
Medium long	0.0000	0.0000	**0.3799**	0.0587	0.5614	0.0000
Long staple	0.0000	0.0000	0.0000	**0.9928**	0.0000	0.0072
ELS	0.0000	0.0000	0.0000	1.0000	**0.0000**	0.0000
Others	0.3176	0.0000	0.3955	0.0000	0.2311	**0.0558**

cotton exports. Based on the above findings, it was concluded that India's cotton production witnessed substantial increase over the years. But the production of ELS and Short staple cotton is shrinking and we are importing the same from African countries, Egypt, Isrel and USA. Hence efforts should be made to encourage production of short staple and ELS verities of cotton to meet the domestic textile industry requirement by improving productivity and quality of fibre in line with the Bt hybrids.

REFERENCES

Anonymous, 1999. Indian cotton and textile industries: Reforming to compete, document of the World Bank, Allied publishers, 121.

Anonymous, 2012. WWF-India Report: Cotton market and sustainability in India.

Anonymous, 2007. Cotton Exporters Guide, International Trade Centre, Geneva, 268.

Anonymous, 2015. Commodity Profile for Cotton-January 2015.

Caesar B.Cororaton and Jatinder S.Bedi, 2008. IFRI Discussion Paper 00801, Cotton Textile Apparel sectors of India situations and challenges faced, International Food Policy Research Institute.

Dhruv Sood, 2014. GAIN Report No.IN4111, Arrivals slow and with lower prices .....MSP operations underway, Cotton and products update, India-2014, 3.

P. Ramasundaram, Suresh A Kurup and Ramesh Chand, 2011. *Manoeuvring Technology for surplus extraction: the case of BT cotton in India*, Policy Brief No. 37, National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi.

Sujatha R.V., K.Suhasini and Y.Eswara Prasad , 2007. *43rd Annual Conference of the Indian Econometric Society,* Department of Humanities and Social Science, IIT Bombay.

Global competitiveness of cotton in Tamil Nadu

S. KANAKA AND M. CHINNADURAI

Department of Social Sciences, Agriculture College and Research Institute, Killikulam - 628 252

Email: kanaka.janu@rediffmail.com

ABSTRACT : This paper combines policy analysis matrix techniques to model the analysis of profitability from cotton cultivation. Policy analysis matrices are computed for a sample of cotton growers located in the dry land of the Tamil Nadu under observed conventional and profit-efficient farming conditions. In this study cotton had been not competitive for most of the period under consideration. EPC estimates showed that it was more than unity like DRC in the most of the study period. However it could be seen that these had been an decreasing trend in the values of EPC and DRC from 2002-2003.Since NPC value are less than unity it indicates that the state had not protected the crop at the farmers level. The estimates of DRC revealed that the state had comparative advantage in cotton export. The main conclusion is that the usefulness of the policy analysis matrix might be substantially enhanced by simulating profitability after efficiency-improving managerial decisions have been adopted.

Key words : Cotton cultivators, DRC, EPC, ERP, Indian agricultural policy, multifunctionality, NPC, policy analysis matrix

This paper evaluates the private and social profitability of farming systems by the use of the policy analysis matrix (PAM). Since the seminal work by Monke and Pearson (1989), the PAM has been widely employed to compute market-driven and social profits for a variety of farming systems under different technological and institutional scenarios. Here, it is shown that important additional insights might be obtained if the farmers' efficient behaviour is considered, in addition to their observed behaviour. This empirical application responds to the concern over whether or not those Tamil Nadu farming systems that can be deemed multifunctional, because of the important environmental functions performed, will be able to survive in the policy context of the post-2003 common agricultural policy (CAP).

For Indian authorities, the political problem of supporting farmers' incomes in an increasingly open economic environment has been further compounded by the need to take on board the impact of trade liberalization on the non-commodity outputs of Indian agriculture. There is a growing recognition that, beyond its primary function of supplying food and fibre, agriculture can provide environmental benefits and contribute to the sustainable management of renewable natural resources, as well as to the preservation of biodiversity, and the maintenance of the economic viability of less favored rural areas. These new concerns are frequently summarized under the heading of multifunctional agriculture and have become an integral part of the Indian model of agriculture (EC, 1999, 2000). The research concerning the multifunctional character of agriculture is no longer restricted to international trade policy.

The impact of agricultural policies on farmers' income might be widely different under observed and efficient behaviors. Likewise, the assessment of private and social profitability for a particular farming system can change substantially after major input adjustment decisions have been adopted in response to the diffusion of best management procedures. Profits obtained after all those adjustments could provide a useful benchmark for current production practices, showing whether enough room exists for an improvement in farms' financial situation. In this paper efficiency is used in connection with the PAM, refers to a social benchmark for the calculation of costs and revenues based on the adoption of international prices and the removal of the effects of subsidization and taxation.

DATA AND SAMPLE:

Tamil Nadu : The study relied on secondary data pertaining to export of major agricultural commodities in Tamil Nadu. The secondary data included production of the groundnut in Tamil Nadu and India, export and import prices, domestic wholesale and world market prices for the periods between 2004-2005 and 2013-2014 at district and state level. These data were collected from various issues of Seasons and Crop Report of Tamil Nadu, Agro Stat published by different sources and web database of Food and Agriculture Organization and IndiaStat. Value of export of agricultural commodities through Chennai and Tuticorin ports was also collected from the custom houses (Sea Cargo) for the periods of ten years (1996-1997 to 2012-2013).

The price data are monthly quotations for nominal spot price (US $/metric ton) for Cotton were collected from UNCTAD website. The data span from January 2004 to December 2014 was collected. The dataset used in this paper corresponds to a sample of 337 single crop cotton farms located in the Tamil Nadu districts. The data were collected from a comprehensive survey carried out by the authors with support from the Tamil Nadu Ministry of Agriculture and correspond to the year 2014. The dataset provides data for one output and seven inputs. Output is measured in lint of cotton production. The only fixed input is cultivated land, measured in hectares. Variable inputs are: labour (working days), in addition to capital, fertilisers, seeds, herbicides and fungicides, all of which are measured in Indian rupees.

Measures of competitiveness

Nominal protection coefficient (NPC) : The Net Protection Coefficients were estimated for cotton lint under exportable hypothesis for the period from 2004-2005 to 2013-2014 in order to measure the extent to which domestic prices diverge from border equivalent prices. It was estimated as follows.

$NPC = P_d/P_b$

Where,

P_d = the domestic producer price; and

P_b = the border equivalent producer price computed as explained below.

Border equivalent prices or world prices adjusted for transport, marketing and processing costs, were estimated to serve as yardstick to indicate the extent to which domestic prices have been distorted by the various government interventions.

Algebraically,

$P_b = P_w - T_w - T_d - C_d + V_b$

Where,

Pb = Border price

Pw = World price

Tw = Ocean freight and insurance charges

Td = Handling, transport and marketing charges from port to domestic markets

Cd = Transport, processing and marketing charges farm gate to domestic market

V_b = The value of by-products.

An NPC greater than one would show that the domestic market price of the commodity exceeded the border price, which discouraged the export of that particular commodity.

Effective protection coefficient (EPC) : In the present study, Effective Protection Coefficient (EPC) was estimated as the ratio of value added in private prices to value added in social prices. The EPC indicates the combined effects of policies in the tradable cotton markets.

$EPC = VP_d / VP_b$

Where,

VP_d = the value added in domestic price (private price)

VP_b = the value added in border price (social price)

An EPC greater than one would indicate positive incentive effects of commodity policy (an export subsidy to producers), whereas an EPC less than 1 shows negative incentive effects (a tax on producers). Both the EPC and the NPC ignored the effects of transfers in the factor market and therefore do not reflect the full extent of incentives to farmers.

Domestic resource cost (DRC) : To measure the comparative advantage (or) efficiency of Indian cotton in the world market, domestic resource cost coefficient was estimated as given below.

$DRC = SP_d / VP_b$

Where,

SP_d = the shadow price of the cotton; and

VP_b = the value added measured at world prices.

DRCs greater than one would indicate that the value of domestic resources used to produce the commodity exceeded its value added in social prices. Production of the commodity, therefore, does not represent an efficient use of the country's resources. DRCs less than one would imply that a country has a comparative advantage in produce in the commodity. Values less than one would mean that the denominator (value added measured at world prices) exceeded the numerator (the cost of the domestic resources measured at their shadow prices).

Effective rate of protection (ERP) : To measure the structure of protection like tariffs, import bans, quantitative restrictions on Indian rice exports, Effective Rate of Protection coefficient was estimated, which measured the percentage increase above value added in world prices that was permitted by the structure of protection.

$EPC = VAD_p / VAB_p$

$ERP = (VAD_p - VAB_p) / VAB_p$

Where,

VAD_p = Value added at domestic price VAB_p = Value added at border price

ERP = EPC – 1 or EPC = ERP +1

Greater the ERP, higher would be the protection for that commodity to be traded in the world markets and vice versa.

In this paper, the PAM methodology is employed in order to learn about the possibilities of maintaining Cotton cultivation in the Tamil Nadu cotton cultivators.

RESULTS AND DISCUSSION

Details of the competing countries : Details of competing countries and their average market share along with the growth rate for the cotton lint for the period from 1996-1997 to 2012-2013 are furnished in the Table 1. As mentioned elsewhere, the details were collected from the website of Food and Agricultural Organization and growth rate was worked out country wise.

USA enjoyed the prime place in the cotton export and it accounted for nearly 40 per cent of the world's cotton export. Next to USA, Uzbekistan had a share of 10.31 per cent of the world cotton export. However these two countries witnessed a negative growth rate during the period of consideration. India occupied third position in the cotton export and the export dwindled down at the rate of 3.6 per cent/annum of the selected countries only. Brazil exhibited a positive growth rate of 2.3 per cent per annum in cotton export though it shared only five per cent of the world total export of cotton. The growth rate of cotton export at world level showed a marginal decline (- 0.8 per cent/annum).

Export competitiveness : Trade competitiveness of the crops was analyzed using the framework of Policy Analysis Matrix. As mentioned elsewhere, the PAM was constructed taking into consideration of free on board prices. Similarly, for domestic factors which are not internationally traded social cost was calculated using the value of marginal product approach using factor shares of various inputs alongwith the mean values of inputs, output and prices.

Nominal Protection Coefficient (NPC), Effective Protection Coefficient (EPC), Effective Rate of Protection (ERP) and Domestic Resource Cost (DRC) computed to reveal the trade competiveness. Trade competitiveness was

Table 1. Competing countries and their average market share

Commodity	Major exporting countries	Quantity (tonnes)	Per cent to Total	CGR (%)
Cotton	USA	3215218	39.90	-0.5**
	Uzbekistan	830693	10.31	-2.7*
	India	**756216**	**9.38**	**-3.6***
	Australia	435253	5.40	-1.3
	Brazil	395771	4.91	2.3*
	Greece	248303	3.08	-0.4
	World	8057933	100.00	-0.8*

*- Significant at ten per cent level; **- Significant at five per cent level;
***- Significant at one per cent level
Source: www.fao.org/crop/statistics/en/

Table 2. Competitive measures for cotton

Year	NPC	EPC	ERP	DRC
2004-2005	0.81	0.68	-0.32	0.67
2005-2006	0.77	0.66	-0.34	0.64
2006-2007	0.74	1.18	0.18	1.16
2007-2008	0.73	1.22	0.22	1.20
2008-2009	0.69	0.71	-0.29	0.69
2009-2010	0.69	1.22	0.22	1.19
2010-2011	0.70	0.95	-0.05	0.92
2011-2012	0.66	1.23	0.23	1.20
2012-2013	0.63	1.32	0.32	1.28
2013-2014	0.66	1.40	0.40	1.36
Average	**0.71**	**1.06**	**0.06**	**1.03**

estimated using the aforesaid measures for cotton for the period from 2004-2005 to 2013-2014.

Export competitiveness of cotton : The estimates of NPC, EPC, ERP and DRC for cotton lint are furnished in Table 2.

The average NPC was less than unity under exportable hypothesis. The average value of EPC was found to be 1.06, indicating in general that the state had not protected the crop. The DRC cotton revealed that Tamil Nadu had comparative disadvantage in cotton export and it can import at cheaper price. The cheaper availability of international cotton was due to the prevalence of subsidies provided by cotton producing countries especially USA and Brazil.

A relatively better performance of cotton crop in the pre WTO period might be due to expansion in area, availability of improved technologies of cotton production technology and its adoption, remunerative support prices and institutional support. But the production started declining after the establishment of WTO due to decrease in area under cultivation, which could be attributed to import of edible oils and relatively stagnant real prices of cotton.

From the foregoing discussion, it is evident that cotton was found to be disadvantage and efforts have to be taken to avert the situation. The measures will be taken by the Government are in the desired direction.

Conclusion : An efficient PAM has been built on the basis of this information, yielding new estimates of private and social profitability. Now, farms are made negative profits and the society also obtains a net welfare gain from the resources allocated to cotton production. It could be argued, with regard to the lack of social profitability of cotton farms with observed data, that social profitability is too narrowly defined in the PAM context, because it does not include a direct appraisal of the worth of the positive environmental externalities that stem from cotton cultivation. The PAM methodology could be extended by including the valuation of the public goods (landscape and biodiversity among them) jointly produced with the private or commercial output in the social row of the matrix. A trade off could then arise between negative economic returns and the production of non-commercial, *i.e.* multifunctional, outputs. However, this line of thinking has not been pursued in this paper.

The lack of relevant empirical information that could be used for widening the scope of social efficiency prevents us from providing a sound justification of private and social losses grounded on society's quest for non-commodity outputs from agriculture. But differences between private and social profits per hectare can be used to establish a lower threshold for the valuation of the annual supply of public good services jointly produced with cotton output. Instead of pursuing a line of analysis that concentrates on the construction of an environmental PAM, the possibilities offered by computing a virtual PAM, assuming profit maximization on behalf of farmers, is explored. This helps to assess whether there is a way out of the current financial difficulties of cotton cultivators are experiencing that could allow the valuable non-commercial functions currently performed by this farming system to be maintained. The findings point to a negative outcome, both in terms of private and social profits, after farmers should be adopt the best practices of efficient farms.

Finally, it is worth highlighting a couple of the conclusions of this research. On the one hand, it vindicates the potential of the policy analysis matrix to yield fruitful information about particular cotton cultivation. Furthermore, the usefulness of this methodological approach may be substantially enhanced if the analyst can simulate the profitability of the system after all sorts of efficiency improving changes have been adopted by farmers. On the other hand, the results of this research lead to a noteworthy conclusion in terms of economic policy. In order to preserve the nonmarketable function of the Tamil Nadu cotton system linked to the protection of biodiversity and the environment, local and regional authorities need to make a greater effort to spread the adoption of best practices among cotton cultivators, helping them to improve their profit efficiency and financial viability.

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REFERENCES

Deodhar, S.Y., 2001. WTO Agreements and Agriculture: Retrospection and Prospects. CMA Monograph No.191. Oxford and IBH Publishing Co.Pvt.Ltd, New Delhi.

EC, 2000. Agriculture's contribution to environmentally and culturally related non-trade concerns. Indian Commission International Conference on Non-Trade Concerns in Agriculture, Ullensvang, Norway, July 2-4. Discussion Paper Four.

Ministry of Commerce and Industry, 2001. India's Proposals on Agriculture-I: Food Security. India and the WTO, V **l.3** : 2.

Pearson S., Gotsch C., Bahri S., 2003. Applications of the policy analysis matrix in Indonesian agriculture. Available on line in http://www.stanford.edu/group/FRI/

Pearson S., Monke E., 1989. Agricultural policy in Kenya. Applications of the policy analysis matrix. Cornell Univ Press, Ithaca, NY, USA. 328 pp.

Reddy, B., Lalith Achoth, D. R. and Chenappa Reddy, B.V., 1998. Export Competitiveness of Groundnut Empirical Evidence from Karnataka. *Astha Vijnana*, Vol.15 (3): pp. 263-270.

www.fao.org/crop/statistics/en/
www.unctad.com
www.indiastat.com

CROP PROTECTION AND BIOSAFETY

Population dynamics of target and non target pests in transgenic cotton

U. B. HOLE, S. M. GANGURDE AND R. W. BHARUD
Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722
E-mail : uttamhole@gmail.com

ABSTRACT : Performance of transgenic cotton hybrid with *Bacillus thuringiensis* (*Bt*) *Cry* 1Ac+*Cry* 1Ab gene alongwith non-transgenic cultivar of *Gossypium barbadense* was evaluated against pest complex under irrigated condition at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. India for two years during rainy season 2012, 2013 and 2014. The results revealed that there were no difference between the transgenic and non-transgenic hybrid in their relative susceptibility to cotton jassids, *Amrasca biguttula biguttula*, thrips, *Thrips tabcaci*, aphids *Aphis gossypi*, white fly, *Bemesia tabaci* and mealy bug, *Phenacoccus solenopsis* . Thus, the transgenic hybrid does not afford any protection to sucking pests of cotton and their tolerance or resistance is mainly dependent on the morphological or genetic base. Bollworm incidence was completely absent in transgenic cotton hybrid as no square and boll damage was observed. Whereas non-transgenic hybrid recorded higher damage (1.18 to 39.19%) and significantly differed from transgenic hybrid (0.36 to 1.56%). Besides this, significant difference in seed cotton yield was also observed during both the cropping season. Seed cotton yield of transgenic hybrid (18.85 q/ha) was significantly greater than that of the non-transgenic hybrid (13.93 q/ha) under protected condition. The results suggested that transgenic hybrid cannot control sucking pests of cotton and there was no difference in sucking pests incidence in transgenic hybrid and non-transgenic hybrid. The major bollworms *Helicoverpa armigera*, *Earias vittella* and *Pectinophora gossypiella* were effectively controlled in transgenic hybrid. Thus, transgenic hybrid can play a major role in combating pest problem thereby reducing insecticide usage in cotton ecosystem and helps to maintain eco balance by conserving natural enemies.

Key words : Bollworms, *Gossypium,* cotton, *Cry* 1Ac , *Cry* 1Ab, natural enemies, sucking pests

Cotton is an important commercial crop in India playing a major role in agricultural economy. Before introduction of transgenic *Bt* cotton, farmers of India witnessed instability in cotton production due to frequent crop failures because of outbreaks of insect pests. Among the pests problems, bollworms especially American Bollworm, *H.armigera* and Pink bollworm *P.gossypiella* cause considerable damage to the cotton crop. *Helicoverpa* alone cause significant losses to the tune of Rs.1000 crores in the country annually warranting insecticides applications which many a times exceeds 20 sprays especially in epidemic years (Prasad *et al.*, 2009). The excessive and indiscriminate use of insecticides in cotton ecosystem has led to development of resistance to insecticides in *Helicoverpa,* resurgence of minor pests and elimination of natural enemies leading to control failures with insecticides. In order to reduce the dependence on chemical insecticides and resultant effect on non target organisms, tools of biotechnology have been applied to develop cotton that can withstand certain problematic and insecticide resistant pests more efficiently.

Transgenic *Bt* cotton is a new technology in plant protection that enables transgenic cotton plant to express a crystal (Cry) toxin called

Cry 1Ac+*Cry* 1Ab, originally derived from the soil bacterium *B.thuringienesis* which is a natural enemy of bollworm pest and the endotoxins produced by bacteria have proved effective against lepidopteran insects (Kennedy, 2008). When the target pest oviposit on the transgenic plant, the larvae hatching from such eggs feed and ingest Cry protein along with plant tissue. The protein acts immediately on the inner linings of digestive system and the young larvae cease feeding and die within 2 to 3 days. As the pest is killed in its early stage, any potential damage to crop is prevented. Transgenic *Bt* cotton containing *Cry* 1Ac+*Cry* 1Ab gene which offers resistance to major bollworms was first commercially released in the world in 1996 (Gouse *et al.,*2004; Wu KM *et al.*, 2008; Choudhary and Gaur, 2010; Hui-Lin Yu *et al.,* 2011) and during 2002 in India (Prasad and Rao, 2008). In the present study, the second generation transgenic *Bt* cotton which was commercialized in India was studied for their reaction to different pests of cotton.

MATERIALS AND METHODS

The field trials were conducted during 2011-2012 and 2012-2013 to evaluate *Bt* hybrid RCH 2*Bt* along with non *Bt* hybrid of *G.barbadense* DCH-32 at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. India under unprotected irrigated conditions for pest incidence and under protected irrigated condition for yield record. The plot size of each hybrid was 2000 sq.m which were sown at a spacing of 90 x 90 cm row to row and plant to plant distance, respectively. The *Bt* cotton genotype RCH 2*Bt* and non *Bt* cotton genotype DCH-32 were sown in the third week of May and all the agronomic practices such as fertilizer application and intercultural operations were similar in these two cotton hybrids. These test hybrids were raised under unprotected condition. Weekly observations on incidence of sucking pests and bollworms were recorded at 10 randomly selected spots on 5 plants along with weather parameters. The sucking pests such as aphids, jassids, thrips and whiteflies were recorded from three leaves, each one from top, middle and bottom canopies of the plant, while the number of mealy bug *P.solenopsis* from 10 cm portion of shoot/5 plants was counted. The american bollworm and spotted bollworm larvae along with per cent square damage and green boll damage were recorded from whole plant. The incidence of pink bollworm larvae was observed through destructive sampling of 20 randomly collected green bolls from each treatment and per cent damage in green bolls were recorded. Thus, the data obtained was subjected to statistical analysis after applying suitable transformations.

RESULTS AND DISCUSSION

Effect of transgenic cotton on sucking pests incidence and natural enemies: Transgenic *Bt* cotton RCH-2*Bt* along with non *Bt* cotton DCH-32 were evaluated against pest complex of cotton under unprotected conditions and the results are presented in Table 1 to 4. The pooled results of two years revealed that the infestation leaf hopper on cotton ranged between 0.40 to 57/3 leaves. The first incidence of aphids was noticed during 27MW (meteorological week). The higher infestation level of 30.80 to 57.00 aphids/3 leaves was observed from 38 to 47MWs, respectively. The population of leaf hopper on cotton ranged between 0.64 to 18.98/3 leaves. The first incidence of jassids was noticed during 27MW. The higher infestation level of 6.44 to 18.98 leaf hoppers/3 leaves was observed from

29 to 42 MWs. The population of jassids crossed the ETL during this period and peaked at 40MW. The incidence of thrips on cotton ranged between 0.18 to 52.88/3 leaves. The first incidence of thrips was observed during 27MW. The high population level of 32.08 to 52.88 thrips/3 leaves was noticed during 33 to 37MW. The population was peaked at 35MW. The infestation whitefly on cotton ranged between 1.78 to 41.52/3 leaves. The first incidence was noticed during 27MW. The higher incidence of 29.66 to 41.52 whiteflies/3 leaves was observed during 44 to 49MW during which population peaked at 49MW. The infestation of mealy bug was first noticed during 35MW in the month of August with the population of 0.83 mealy bugs/10cm shoot. The population varied from 0.83 to 35.35 mealy bugs/ 10cm shoot. The higher incidence of 35.35 mealy bugs/10cm shoot was noticed during 45MW.

The population of natural enemies *viz.*, *Coccinellids, Chrysopids, Apanteles, Anagyrus, Cryptolaemus,* syrphids and spiders varied from 0.70 to 9.69 predators/plant. The parasitisation due to *Anaseus bambawalei* endoparasitoid caused mummification of mealy bugs.

In the similar type of study Vennila *et al.* (2004) reported that transgenic *Bt* cotton does not afford any protection to sucking pests of cotton and their relative tolerance or resistance is mainly dependent on the morphological or genetic base which is in accordance with Reed

Table 1. Population dynamics of key pests of DCH-32 cotton in relation to climatic conditions.

StandardMW	Sucking pests/3 leaves					Pred-ators/ plant	Abiotic factors				
	Aphids	Jassids	Thrips	Whitefly	Mealy bug/ plant		Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
							Maxi-mum	Mini mum	Morn-ing	Even ing	
July 27	30.84	5.12	7.70	2.16	0.00	3.23	31.4	23.1	77.7	61.1	11.8
28	31.74	3.96	7.56	4.60	0.00	1.42	29.9	22.7	78.1	69.1	8.6
29	20.80	5.88	10.02	3.48	0.00	1.27	25.8	21.9	90.3	85.3	65.2
30	20.92	3.76	15.36	2.34	0.00	1.15	29.0	22.6	84.1	66.7	22.8
Aug 31	22.52	4.38	15.04	4.42	0.00	1.25	28.2	21.9	81.0	70.6	21.2
32	19.92	6.68	11.62	3.06	0.00	1.57	29.7	21.9	78.7	64.0	1.0
33	10.08	8.02	20.68	5.28	0.00	1.45	30.2	22.1	78.1	59.0	2.6
34	7.18	5.12	34.80	2.46	0.00	1.27	29.2	21.8	78.7	63.9	13.4
35	27.24	4.66	44.94	11.48	0.83	4.56	31.5	20.4	78.3	50.0	—
Sept.36	0.40	2.84	28.50	9.40	2.24	2.37	32.3	19.7	79.3	49.9	7.7
37	0.72	3.20	14.82	14.70	4.37	4.59	31.4	22.0	81.7	60.1	6.7
38	12.58	4.84	4.40	12.68	6.25	4.13	29.6	21.5	83.7	60.6	6.5
39	10.56	5.32	1.80	10.34	7.58	4.21	30.5	21.1	80.0	56.0	—
Oct. 40	9.26	17.94	1.50	16.74	13.26	5.13	31.9	21.9	81.6	58.0	4.0
41	20.66	4.26	0.66	8.36	14.81	2.69	31.1	20.0	77.1	57.1	9.4
42	21.88	5.82	3.50	14.62	13.10	5.67	32.0	20.1	74.9	46.0	—
43	35.46	1.86	0.40	17.40	20.43	4.36	31.2	19.6	68.4	55.7	5.2
Nov. 44	40.80	3.80	0.28	31.12	18.13	9.67	31.4	16.9	63.3	47.7	—
45	43.82	2.64	0.82	34.78	14.20	9.69	30.6	14.6	65.0	35.6	0.0
46	44.86	2.40	2.64	25.94	19.26	7.29	29.4	12.7	60.4	30.7	—
47	49.54	1.54	0.36	11.12	17.53	3.76	31.0	13.5	67.9	36.6	6.0
48	12.42	1.46	0.42	4.72	12.81	0.87	29.2	6.7	75.1	54.0	—
Dec 49	9.84	0.64	0.18	2.76	7.43	0.84	29.0	9.8	72.3	38.1	—

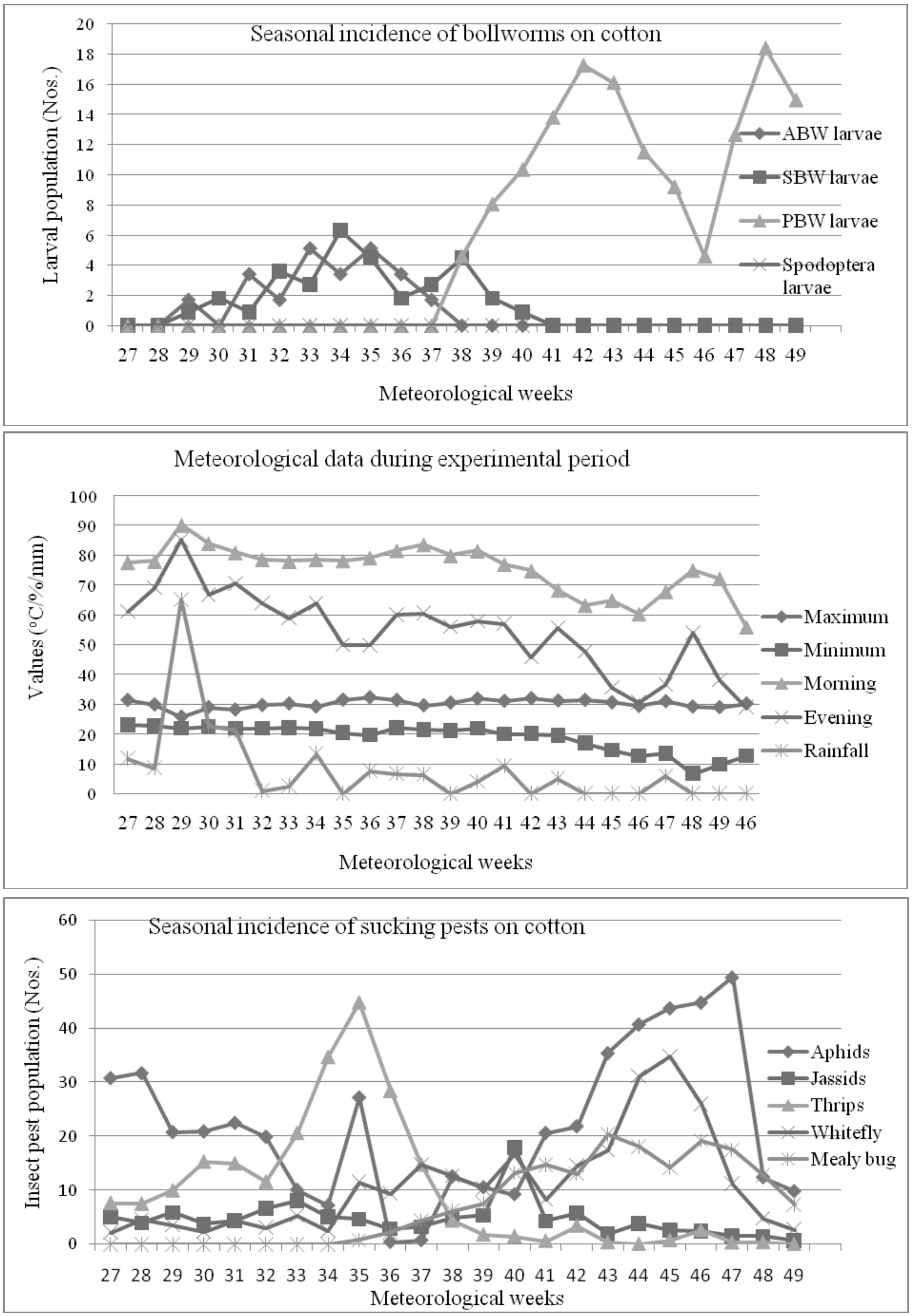

Fig. 1. Seasonal incidence of major pests of cotton and its relationship with meteorological parameters.

Table 2. Population dynamics of key pests of RCH 2 Bt cotton in relation to climatic conditions.

Standard MW	Sucking pests/3 leaves					Pred-ators/ plant	Fruiting body damage (%)	Abiotic factors				
	Aphids	Jassids	Thrips	Whitefly	Mealy bug/ plant			Temperature (⁰C)		Relative humidity (%)		Rainfall (mm)
								Maxi-mum	Mini mum	Morn-ing	Even ing	
July 27	0.00	4.36	8.15	2.88	0.00	1.32	0	31.4	23.1	77.7	61.1	11.8
28	1.66	3.68	7.87	3.64	0.00	0.70	0	29.9	22.7	78.1	69.1	8.6
29	5.88	9.14	12.06	2.36	0.00	1.24	0	25.8	21.9	90.3	85.3	65.2
30	9.36	6.44	26.56	1.78	0.00	0.70	0	29.0	22.6	84.1	66.7	22.8
Aug 31	22.71	11.60	22.13	4.72	0.00	1.32	0	28.2	21.9	81.0	70.6	21.2
32	26.88	17.84	20.66	4.18	0.00	1.38	0	29.7	21.9	78.7	64.0	1.0
33	11.68	9.66	36.94	8.32	0.00	1.70	0	30.2	22.1	78.1	59.0	2.6
34	21.70	7.40	32.08	6.16	0.00	1.78	0	29.2	21.8	78.7	63.9	13.4
35	32.30	5.84	52.88	14.12	12.22	1.88	0	31.5	20.4	78.3	50.0	—
Sept.36	27.24	3.52	43.52	13.36	9.10	4.84	0	32.3	19.7	79.3	49.9	7.7
37	19.80	7.08	36.26	17.74	15.14	3.97	0	31.4	22.0	81.7	60.1	6.7
38	36.46	11.30	15.40	14.58	13.02	2.72	0	29.6	21.5	83.7	60.6	6.5
39	30.80	16.50	6.24	10.40	11.52	4.31	0	30.5	21.1	80.0	56.0	—
Oct. 40	18.40	18.98	4.32	19.20	17.12	5.83	0	31.9	21.9	81.6	58.0	4.0
41	25.16	8.48	4.50	15.22	8.54	5.35	0	31.1	20.0	77.1	57.1	9.4
42	32.38	12.96	2.86	13.08	15.94	6.28	0	32.0	20.1	74.9	46.0	—
43	47.10	5.06	2.62	28.84	17.18	5.64	0	31.2	19.6	68.4	55.7	5.2
Nov. 44	42.62	4.42	0.48	16.12	31.68	6.81	0	31.4	16.9	63.3	47.7	—
45	49.22	3.26	1.54	23.12	35.35	7.50	0	30.6	14.6	65.0	35.6	0.0
46	55.36	3.38	1.46	22.20	26.40	3.91	0	29.4	12.7	60.4	30.7	—
47	57.00	2.04	1.28	29.66	11.82	2.36	0.36	31.0	13.5	67.9	36.6	6.0
48	29.80	1.40	0.94	38.00	3.54	1.96	1.20	29.2	6.7	75.1	54.0	—
Dec 49	17.26	0.88	0.66	41.52	2.07	1.41	1.56	29.0	9.8	72.3	38.1	—

et al., (2000) and Bambawale *et al.* (2004) who reported that the incidence of sucking pests was more or less similar in both *Bt* and non *Bt* hybrids. However, the present results contradict with findings of Radhika *et al.*, 2004; Abro *et al.*, 2004; Cui and Xia, 2000, who reported that the incidence of sucking pests was high in *Bt* hybrids than their non *Bt* counterparts.

Effect of transgenic cotton on bollworms density and fruiting body damage : The number of *Helicoverpa* eggs recorded on cotton crop varied from 0.46 to 3.22 eggs/5plants. The larval population varied from 1.70 to 5.10 larvae/5plants. The higher incidence of 3.40 to 5.10 larvae/5 plants was noticed during 31 to 37MW. The infestation on green fruiting bodies ranged from 1.18 to 5.27 per cent. The number of spotted bollworm larvae varied from 0.90 to 6.30 larvae/5 plants. But the higher larval incidence of 3.60 to 6.30 larvae/5 plants was noticed during 32 to 38MW. The incidence on green fruiting bodies ranged between 0.72 and 5.32 per cent. The number of pink bollworm (PBW) larvae observed in 20 infested green bolls varied from 4.60 to 18.40 larvae. The higher incidence of 10.35 to 18.40 PBW larvae/20 infested green bolls was observed during 40 to 49MW. The infestation of bollworms on green fruiting bodies was noticed from 29 to 49MW and the higher incidence of bollworms was noticed from 32 to 49MW. The open boll and locule damage varied from 7.46 to 39.19 and 4.08 to 15.10 per cent, respectively. The overall infestation of bollworms on fruiting bodies (squares, bolls and locules) varied from 1.18 to 39.19 per cent.

The *Helicoverpa* moth catches varied from 1 to 5 adults/trap during 31 to 40 MW and the catches of spotted bollworm adults varied from 1 to 81 moths/trap during 30 to 48MW. The population of pink bollworm moth varied from 2 to 140 adults/trap during 32 to 49MW. But the higher catches of pink bollworm moth noticed during 42MW. The *Spodoptera* adult catches varied from 1 to 151/trap but higher catch was noticed during 32 to 35MW. The adults of *S.litura* were trapped in pheromone traps but incidence of larvae was not observed in cotton field throughout the season.

In RCH 2*Bt*, the incidence of american bollworm, *H.armiger*a and spotted bollworm *E.vitella* were completely absent, as no square damage and green boll damage was observed. However, open boll damage was recorded upto 0.36 to 1.56% by pink bollworm *P.gossypiella* which significantly lower than the non *Bt* cotton hybrid DCH-32. Comparatively, the highest green boll damage, open boll damage and open boll damage was observed in DCH-32.

The results clearly indicate that transgenic *Bt* cotton is highly effective against the most problematic pest in cotton which has developed many fold resistance to chemical insecticides. The present findings are in conformity with Krishnamurthy and Subramanian (2004) who reported that fruiting body damage was very low in MECH-12, MECH-162 and MECH-184 *Bt* hybrids over the respective non *Bt* counter parts and Bhatade *et al.,* (2006)

Table 3. Population dynamics of key pests of cotton in relation to climatic conditions.

Standard MW	*H. armigera*/ 5 plants		*Earias* spp larvae/ 5 plants	PBW larvae/ 20 green bolls	*S. litura* larvae/ 5 plants	Fruiting body damage (%)	Trap catches/week			
	Egg	Larvae					*H. armigera*	PBW	SBW	*S. litura*
July 27	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0
28	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0
29	0.92	1.70	0.90	0.00	0	1.18	0	0	0	1
30	0.00	0.00	1.80	0.00	0	3.13	0	0	1	2
Aug 31	1.84	3.40	0.90	0.00	0	4.50	2	0	3	3
32	0.00	1.70	3.60	0.00	0	7.52	0	13	67	80
33	2.76	5.10	2.70	0.00	0	4.94	3	19	69	120
34	1.38	3.40	6.30	0.00	0	7.99	2	13	81	151
35	3.22	5.10	4.50	0.00	0	5.38	3	7	24	150
Sept.36	0.92	3.40	1.80	0.00	0	4.63	5	10	2	10
37	0.46	1.70	2.70	0.00	0	2.66	2	9	5	15
38	0.46	0.00	4.50	4.60	0	8.68	3	13	18	29
39	0.00	0.00	1.80	8.05	0	16.19	3	7	10	15
Oct. 40	0.00	0.00	0.90	10.35	0	14.01	1	5	15	25
41	0.00	0.00	0.00	13.80	0	27.61	0	3	7	16
42	0.00	0.00	0.00	17.25	0	37.37	0	140	3	4
43	0.00	0.00	0.00	16.10	0	32.09	0	2	5	1
Nov. 44	0.00	0.00	0.00	11.50	0	27.14	0	5	2	58
45	0.00	0.00	0.00	9.20	0	23.16	0	8	1	48
46	0.00	0.00	0.00	4.60	0	21.18	0	6	4	23
47	0.00	0.00	0.00	12.65	0	27.14	0	5	6	14
48	0.00	0.00	0.00	18.40	0	39.19	0	3	4	13
Dec 49	0.00	0.00	0.00	14.95	0	31.58	0	5	0	0

findings of 89% reduction in square damage in *Bt* cotton over their non *Bt* hybrids due to *Helicoverpa*. The inbuilt resistance of transgenic *Bt* cotton to *Helicoverpa* was proved by many researchers by reporting very low larval population, low square and boll damage in *Bt* cotton hybrids than their non *Bt* counter parts and conventional cotton (Cui and Xia, 2000; Kranthi, 2002; Gore *et al.*, 2003; Vennila *et al.*, 2004). Transgenic *Bt* cotton hybrids also offered protection against pink bollworm which is a late season pest in cotton. RCH 2*Bt* has not shown the incidence of pink bollworm upto 150 DAS and superior compared to DCH-32 non *Bt* hybrid in the experiment in which fruiting body damage ranged from 1.18 to 39.19%. The results are in accordance with findings of Hugar *et al.,* (2006) who reported that fruiting damage to pink bollworm was 3.2% in RCH 2*Bt* as against 18.72% in NCH 145 non *Bt* cotton. Pink bollworm is not visible on the plant and completes most of the life cycle in the unopen boll itself and the damage in the form of stained and discoloured kapas is seen only after bursting of the boll. Since the damage is not visible before boll opening it is very difficult to time the application of insecticides for taking control measures. The transgenic *Bt* cotton with *Cry* 1Ac+*Cry* 1Ab toxin can able to control pink bollworm, as toxins are expressed in the plant parts itself and mostly prevents insecticide application and problems of decision making for control options. The resistance of *Bt* hybrids against pink bollworm was proved earlier by many scientists which are

Table 4. Population dynamics of key pests of cotton in relation to climatic conditions.

Std. MW	*H.armigera* av. % infes.on GFB	*E. vittella* av.% infes. on GFB	*S.litura* av. % infes. on GFB and leaves	*P.gossypiella* av. % infes. on		Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
				GFB and open boll	Locule	Maximum	Minimum	Morning	Evening	
July 27	0	0	0	0	0	35.6	24.2	55	33	0.0
28	0	0	0	0	0	36.4	23.8	65	39	27.2
29	0	1.18	0	0	0	34.9	23.7	63	38	0.0
30	1.57	1.56	0	0	0	34.8	23.5	67	40	2.2
Aug 31	1.70	2.80	0	0	0	31.5	23.5	74	56	43.4
32	2.20	5.32	0	0	0	32.2	23.4	71	53	4.8
33	1.78	3.16	0	0	0	31.5	23.7	75	58	3.6
34	5.27	2.72	0	0	0	29.7	23.6	73	63	1.0
35	3.18	2.20	0	0	0	29.6	23.4	77	68	23.6
Sept.36	2.46	2.17	0	0	0	30.6	22.7	80	55	0.8
37	1.18	1.48	0	0	0	31.5	21.6	75	57	0.0
38	0	1.22	0	7.46	4.08	32.5	21.9	73	48	0.0
39	0	1.10	0	15.09	7.18	30.2	22.8	79	62	31.4
Oct. 40	0	0.72	0	13.29	6.79	29.6	22.8	81	64	60.2
41	0	0	0	27.61	11.23	30.1	22.2	76	62	15.8
42	0	0	0	37.37	15.10	30.4	21.5	86	57	69.0
43	0	0	0	32.09	11.97	31.6	20.3	82	48	0.0
Nov. 44	0	0	0	27.14	9.34	31.4	21.8	87	62	118.6
45	0	0	0	23.16	7.86	32.1	19.7	79	41	0.0
46	0	0	0	21.18	6.93	32.2	16.9	75	32	0.0
47	0	0	0	27.14	8.82	31.5	19.4	76	39	18.6
48	0	0	0	39.19	13.46	30.0	15.6	63	40	0.0
Dec 49	0	0	0	31.58	10.23	31.7	15.0	62	34	0.0

in accordance with the present results [Gianessi and Carpenter (1999); Henneberry and Jech (2000)].

Effect of transgenic cotton on yield: Seed cotton yield from fully opened bolls was picked up manually, dried in the sun, weighed and expressed as kilogram per hectare. There were 2-3 pickings in each season, depending upon the length of the growing season. Seed cotton yield was recorded separately for the first, second and third pickings. The pooled results of two years reveled that under protected condition, the RCH-2*Bt* produced the highest seed cotton yield (18.85 q/ha); which was significantly greater than non-transgenic cotton hybrid DCH-32 (13.93 q/ha). Under completely unprotected condition, the transgenic RCH-2*Bt* recorded 5.78 q/ha; while non-transgenic cotton DCH-32 produced only 1.24 q/ha seed cotton yield. Thus, there was significant difference in seed cotton yield of *Bt* and non *Bt* cotton under protected and unprotected irrigated condition. The seed cotton yield of *Bt* cotton in all picking were significantly greater than non *Bt* cotton under both unprotected and protected conditions.

CONCLUSION

From the present findings, it can be concluded that *Bt* cotton cannot control sucking pests of cotton and there is no difference in sucking pests incidence in *Bt* and non *Bt* cotton hybrid. The major bollworms *H.armiger*a, *E.vitella* and *P.gossypiella* are effectively controlled in *Bt* cotton hybrids. The transgenic *Bt* cotton can play a major role in combating pest problem, thereby reducing the insecticide usage on cotton ecosystem and helps to maintain eco balance by conserving natural enemies.

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REFERENCES

Abro, G.H., Syed, T.S., Tunio, G.M. and Khuhro, M.A. 2004. Performance of transgenic *Bt* cotton against insect pest infestation. B*iotechnology,* **3 :** 75-81.

Bambawale, O.M., Singh, A., Sharma, O.P., Bhosle, B.B., Lavekar, R.C., Dhandapani, A., Kanwar, V., Tanwar, R.K, Rathod, K.S., Patange, N.R. and Pawar, V.M. 2004. Performance of *Bt* cotton (MECH-162) under Integrated Pest Management in farmers' participatory field trial in Nanded district, Central India. *Curr. Sci,* **86 :** 1628-33.

Bhatade, S .S, Bhosle, B. B., Ghute, V. G., More, D. G, Deshmukh, P. R., Wajerwadekar, S. J. A. and Phad, D. S. 2006. Comparative performance of *Bt* and non *Bt* cotton hybrids under rainfed conditions of Marathwada region of Maharashtra state. Proceedings of national seminar on transgenic crops in Indian Agriculture: status, risks and Acceptance: Souvenir, Extended summaries and Abstracts, 2006 CCS HAU, Hissar pp.25-26 (S.K. Sethi, S.S. Siwach and R.K. Yadav eds.), January 28-29.

Choudhary B and Gaur K. 2010. *Bt* **Cotton in India: A Country Profile. ISAAA Series of Biotech Crop Profiles. ISAAA: Ithaca, NY.**
Cui, J.J. and Xia, J.Y. 2000. Effects of *Bt*

(*Bacillus thuringiensis*) transgenic cotton on the dynamics of pest population and their enemies. *Acta Phytophylacica Sinica,* **27 :** 141-45

Gianessi, L.P. and Carpenter, J.E. 1999. Agricultural Biotechnology: Insect control benefits, National center for Food and Agricultural Policy. http: //www.bio.org/food & ag/ncfap/ag_bio.htm (1999, July 8).

Gore, J., Leonard, B.R. and Jones, R.H. 2003. Influence of agronomic hosts on the susceptibility of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) to genetically engineered and non-engineered cottons. *Environmental Entomology,* **32 :** 103-10

Gouse M, Pray C and Schimmelpfenning, D. 2004. The distribution of benefits from *Bt* cotton adoption in South Africa. *AgBioForum* **7 :** 187-94.

Henneberry, T.J. and Jech, L.F. 2000. Seasonal pink bollworm, *Pectinophora gossypiella* (Saunders) infestations on transgenic and non-transgenic cottons. *Southwestern Entomologist,* **25 :** 273-86.

Hugar, P S., ThulasiRam, K. and Mudalagiriyappa. 2006. Performance of transgenic cotton in Thungabadra project area of Northern Karnataka. Proceedings of *National Seminar on transgenic crops in Indian Agriculture: status, Risks and Acceptance*. Souvenir, Extended summaries and Abstracts 28-29 January, 2006, CCS HAU, Hissar, 127-29.

Hui-Lin Yu, YH Li and Kong-Ming Wu. 2011. Risk assessment and ecological effects of transgenic *Bt* crops on non-target organisms. *Journal of Integrative Plant Biology*, "Accepted Article"; doi: 10.1111/j.17447909.2011.01047.

Kennedy. 2008. Integration of insect-resistant genetically modified crops within IPM programs. In: Romeis J, Shelton AM, Kennedy GG, Eds. Integration of Insect-Resistant Genetically Modified Crops With IPM Programs. Springer, Berlin, Germany. pp. 1-26.

Kranthi, K.R. 2002. Modalities of *Bt* cotton cultivation in India: Its Pros and Cons including Resistance Management and Potential Ecological impact. Proceedings of *National Seminar on Bt cotton scenario with special reference to India*. 23rd May, Dharwad, 26-50 PP.

Krishnamurthy, S. V. and Subramanian, S. 2004. Evaluation of transgenic *Bt* cotton hybrids. Abstracts of *National symposium on changing world order cotton Research, Development and Policy in context* August 10-12, 2004, ANGRAU, R.nagar, Hyderabad 35 PP.

Prasad, NVVSD, Rao, M. and Rao N.H. 2009. Performance of *Bt* cotton and non *Bt* cotton hybrids against pest complex under unprotected conditions. *Jr. Biopesticides,* **2 :** 107-10.

Prasad, NVVSD and Rao N.H. 2008. Field evaluation of *Bt* cotton hybrids against insect pest complex under rain fed conditions. *Indian Journal Entomology,* **4 :** 367-70.

Radhika, P., Sudhakar, K., Basha Mohiddin, S. and Prasada Rao, G.M.V. 2004. Relative incidence of pest complex on *Bt* and non *Bt* cotton hybrids under protected and unprotected conditions. Proceedings of *National symposium on "Strategies for Sustainable Cotton Production - A Global vision–* 3. Crop Protection" 23-25, November, 2004, UAS, Dharwad.136-138 PP.

Reed, J.T., Stewart, S., Laughlin, D., Harris, A., Furr, R.,Ruscoe, A. and Dugger, P. 2000. *Bt* and conventional cotton in the hills and delta of Mississippi: 5 years of comparison. Proceedings of *Beltwide Cotton Conference*, San Antonia, USA, **2 :** 1027-30.

Vennila, S., Biradar,V.K., Gadpayle, J.G., Panchbhai, P.R.,Ramteke, M.S., Deole, S.A. and Karanjkar, P.P. 2004. Field evaluation of *Bt* transgenic cotton hybrids against sucking pests and bollworms. *Indian Journal of Plant Protection,* **32 :** 1-10.

Wu KM, Lu YH, Feng HQ, Jiang YY, Zhao JZ.2008. Suppression of cotton bollworm in multiple crops in China in areas with *Bt* toxin containing cotton. *Science* **5896** : 1676-78.

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Population dynamics of cotton insect pests in scarce rainfall zone of Andhra Pradesh

A.S.R., SARMA, Y. RAMA REDDY, S. JAFFAR BASHA, AND Y. PADMALATHA

Acharya N.G. Ranga Agricultural University, Regional Agricultural Research Station, Nandyal-518 501

E-mail : sharmarars@gmail.com

ABSTRACT : Field experimentswere conducted during *kharif*, 2010-2011 and 2011-2012 at RARS, Nandyal with test hybrid, DCH 32 for the incidence of sucking pests. The results revealed that the leafhopper population attained two peaks differently in both the years. During 2010-2011, leafhoppers attained first peak during47th standard week and the second peak during 1ststandard week of 2011whereas during 2011-2012, leafhoppers attained its first peak during 38th standard week followed by second peak during 44th standard week. However, though the incidence of other sucking pests like thrips, aphids and whitefly was there, their population was below the ETL during both the years. Among bollworms, the incidence of *Helicoverpa armigera* and *Spodoptera litura* larvae was negligible during the cropping period in both the years. However, during 2010-2011, the mean trap catches of *Helicoverpa* were highest during 50th standard week whereas the moth catches attained peak during 39th standard week in the year 2011-2012. The incidence of *Spodoptera litura* was observed throughout the season in both the years. During 2010-2011, the moth catches of *S. litura* were peak during 40th std. week whereas during 2011-12, it was during 38th std. week and the second peak was attained in46th and 51st standard weekduring 2010-11 and 2011-2012, respectively. The highest pink bollworm moth catches were recorded during 4th standard week during 2010-2011 whereas the moth catches attained peak during 47th standard week during 2011-2012. The correlation studies between the leafhoppers, whitefly and aphid population with temperature (both maximum and minimum), relative humidity (both morning and evening) and rainfall was found non significant whereas thrips population showed a significant and positive correlation with both maximum temperature (r = 0.4986) and minimum temperature (r = 0.4645) during 2010-2011. The correlation between the trap catches of *Helicoverpaarmigera* showed a significant but negative correlation with both maximum (r = -0.5644) and minimum temperature (r = -0.5161) during 2010-2011 whereas the correlation was significant and positive with maximum temperature (r= 0.6089) during 2011-2012. The trap catches of pink bollworm showed a significant but negative correlation with minimum temperature (r = -0.7997), morning relative humidity (r = -0.5991) and evening relative humidity (r = -0.8559) during 2010-2011 whereas the correlation between moth catches of pink bollworm and all the weather parameters tested was non significantduring 2011-2012.

Key words: Abiotic factors, cotton, sucking pests

Cotton (*Gossypium*spp.) is the most important commercial crop in India and plays a vital role in agricultural, industrial, social and monetary affairs of the country. About 60 million people of the country are involved directly or indirectly in cotton production, processing, textiles and related activities. India is the only country in the world where all the four cultivated species of cotton, *viz., Gossypium arboreum* L., *G. hirsutum* L., *G. herbaceaum* L. and *G. barbadense* L. along with intra and inter specific hybrids are cultivated. The production and productivity in India is of great concern owing to the demand for cotton all over the world. Insect pests are the major bottle necks for the poor yields in cotton. Cotton is attacked by a herd of insect pests. During the crop growth period, about 148 insect pests have been recorded on cotton, out of which only 17 species have been reported as major insect pests of cotton (Abbas, 2001). Cotton insect pests can primarily be divided into sucking pests and bollworms. After the introduction of *Bt* cotton during 2002, the bollworm attack has drastically reduced and the sucking pests gained major importance. Among the sucking pests, leafhoppers, mirids in south India and whitefly in north India are of immense importance. Weather plays a key role which influence the incidence of the major insect pests. To develop long term forecasting models, the relationship between incidence of the major insect pests and the weather parameters need to be investigated. Therefore, a thorough understanding of interaction between crop growth stage, pest dynamics in relation to meteorological parameters is a pre requisite for weather based pest forecasting model. Hence, the present study was focused on location specific seasonal occurrence of insect pests and their relationship with weather parameters for formulating timely and effective management strategies for mitigating the insect pests of cotton.

MATERIALS AND METHODS

Present investigation on the population dynamics of sucking pests in cotton was carried out on test hybrid, DCH 32 during *kharif*, 2010-2011 and 2011-2012 at Regional Agricultural Research Station, ANGRAU, Nandyal, Kurnool District, Andhra Pradesh. The crop was grown in a plot size of 1000 m^2at a spacing of 90 × 60 cm and the crop was kept unsprayed throughout the cropping season. All agronomic practices as per the recommendations were followed to raise the crop except for crop protection measures. The population of sucking insect pests was estimated from five locations and in each location on 10 plants selected randomly. On each plant, the populations were estimated from three fully formed leaves one each at upper, middle and lower part of the crop canopy before 10 AM everyday throughout the cropping season. For recording bollworm data, sucking pests were managed by spraying monocrotophos @ 1.6ml/l and with *neem* oil @5ml/l. The bollworm moth catches were recorded daily using pheromone traps in the field.

The data obtained were converted to mean population by using the following formula:

Mean (X) = Óx /N

Where N= Number of plants

Óx = Sum of population of all plants

The mean population data obtained from weekly observations were subjected to simple correlation analysis with meteorological parameters, viz. temperature (maximum and minimum), relative humidity(morning and evening) and rainfall.

RESULTS AND DISCUSSION

The resultsrevealed that during 2010-2011, the incidence of leafhoppers was noticed throughout the cropping period with two peaks. First peak during the 47th standard week with 7.85 leafhoppers/3 leaves and the second peak was observed during 1st standard week of 2011 with 9.40 leafhoppers/ 3 leaves. Though the incidence of thrips, aphids and whitefly was observed, it was below ETL during the crop period (Table 1).

The incidence of *Helicoverpa armigera* and *Spodoptera exigua* in the field was negligible during the cropping period. However, the mean trap catches of *Helicoverpa* were highest during 50th standard week of 2010 (1.89 moths/trap/week) followed by 1st standard week of 2011 whereas trap catches of *Spodoptera exigua* were highest during 52nd standard week of 2010(3.29 moths/trap/week). The incidence of *Spodoptera litura* was observed throughout the season with peak mean trap catches during 40th standard week (15.71 moths/trap/week) followed by 46th standard week (15.50 moths/trap/week). The incidence of pink bollworm was started during 44th standard week (0.86 moths/trap/week) and reached a peak during 4thstandard week of 2011 (22.78 moths/trap/week)(Table 1).

The correlation studies between the leafhoppers, whitefly and aphid population with temperature (both maximum and minimum), relative humidity (both morning and evening) and rainfall was found non-significant whereas thrips population showed significant and positive correlation with both maximum temperature (r = 0.4986) and minimum temperature (r = 0.4645). The present findings are in conformity with Shivanna *et al.*, (2011) who reported that thrips population had a significant and positive correlation with maximum temperature. Vennila *et al.*, (2007a and c) reported that high temperature and scanty rainfall aggravate the severity of sucking pests and also reported that *Thrips tabaci* has population peaks during dry spell with high temperature and low humidity which are optimum for population build up.However, the correlation between thrips population and relative humidity (both morning and evening) and rainfall was non-significant(Table 2).

The correlation between the trap catches of *Spodoptera litura* and *S. exigua* and all the weather parameters tested was non-significant. However, the moth catches of *Helicoverpaarmigera* showed a significant but negative correlation with both maximum (r = -0.5644) and minimum temperatures (r = -0.5161) whereas correlation with other weather parameters was non significant. The results are in conformity with Hameed *et al.*, (2015) who reported that there was a significant and negative correlation between moth catches of *H. armigera* and minimum temperature whereas the results are in negation with Yogesh and Rajnish Kumar (2014) who reported that the moth catches of *H. armigera* showed a significant and positive correlation with minimum temperature. Pink bollworm showed a significant but negative correlation with minimum temperature (r = -0.7997), morning (r = -0.5991) and evening (r = -0.8559) relativehumidity (Table 2).

The results obtained during 2011-2012 revealed that the incidence of leafhoppers was noticed throughout the cropping period with two peaks. First peak during the 38th standard week with 6.25 leafhoppers /3 leaves and the second peak was observed during 44th standard week with 6.65 leafhoppers / 3 leaves. Though the incidence of thrips, aphids and whitefly was observed, it was below ETL only during the cropping period (Table. 3).

The incidence of *Helicoverpaarmigera* and *Spodoptera exigua*larvae in the field was negligible during the cropping period. However, the mean trap catches of *Helicoverpa*were highest during 39th standard week (4.80 moths/trap/week) followed by 46th standard week (2.20 moths/trap/week). On the other hand, the incidence of *Spodoptera litura* in the pheromone traps was observed throughout the crop season with peak mean trap catches during 38th standard week (45 moths/trap/week) followed

Table 1. Population dynamics of insect pests of cotton and weather conditions at RARS, Nandyal during 2010-2011

Std. Week	Sucking pests/ 3 leaves				Natural enemies/plant		Bollworm trap catches				Abiotic factors				
	Leaf hoppers	Thrips	White flies	Aphids	Lady birds	Spiders	*H. armigera*	*S. litura*	*S. exigua*	*P. gossypiella*	Temp. Max. (^{0} C)	Temp. Min. (^{0} C)	RH Mor. (%)	RH Eve. (%)	Rain fall (mm)
39(24thto 30th Sep)	2.41	0.45	0.08	0	0	0.15	1	8	0	0	32.6	24.5	85	78.4	4.4
40(1st to 7th Oct)	4.33	0	0.1	0	0	0.05	0	15.71	0.43	0	33.9	23.8	70.3	59.1	0
41(8th to 14th Oct)	2.96	0.86	0.16	0	0	0.26	0	2.24	0.06	0	34.2	24	85.2	77.2	1.4
42(15th to 21st Oct)	2.36	0.4	0.56	0	0.05	0.05	0	0	0	0	31.6	23.8	89.7	77.7	51.8
43(22nd to 28th Oct)	1.91	0	0.11	0	0	0	0	0	0.04	0	31.19	23.27	88.57	74.57	18.2
44(29th Oct to 4th Nov)	0	0	0	0	0	0	0.43	1.57	0.71	0.86	29.07	22.94	88.29	77.43	7
45(5th to 11th Nov)	6.65	0	1.25	0.5	0	0.2	0.43	6.43	0.57	2.29	30.93	22.84	82	75.29	11.8
46(12th to 18th Nov)	0	0	0	0	0	0	0.8	15.5	0.9	2.1	31.24	21.91	83.09	73.18	71.5
47(19th to 25th Nov)	7.85	0	0.7	0	0	0.25	1.57	7.29	0.71	2	30.9	21.6	83.5	67	48.8
48(26thNov to 2nd Dec)	4.7	0	0.15	0	0	0	1	1.29	1.29	1.29	28.9	20.7	85.7	67.7	0
49(3rdto 9th Dec)	6.05	0	0.25	0	0	0	0.86	7.29	1.57	4.43	30.5	20.4	76	60.7	13.4
50(10th to 16th Dec)	5.63	0	0.4	0	0	0.1	1.89	6.11	0.78	2.89	30.2	14.9	76.8	48.8	0
51(17th to 23rd Dec)	4.65	0	0.25	0	0	0	1.71	2.14	0.71	14	25.05	13.4	74.8	49.5	0
52(24th to 31st Dec)	5.22	0	0.33	0	0	0	1.71	1.71	3.29	7.14	28.52	18.52	80.4	56.8	0
1(1st to 6th Jan 2013)	9.4	0	0.1	0	0.15	0.5	1.75	1	0.63	4.75	29.23	18.23	75.57	55.86	0
2(7th to 13th Jan)	3.35	0	0.15	0.05	0	0	1.44	0.89	0.89	11.89	30.76	14.49	64	32.71	0
3(14th to 20th Jan)	2.35	0	0	0	0	0	0.5	0.5	0	19.17	32.47	15.6	73.71	33	0
4(21st to 27th Jan)	3.21	0	0	0	0.05	0.05	0.11	0	0	22.78	31.8	15.61	75.5	35	0
5 (28th Jan to 3rd Feb)	2.45	0	0.35	0	0	0	0	0	0	11.67	29.23	18.23	75.57	55.86	0

Table 2. Correlation between insect pests and weather parameters during 2010-2011

Pests	Temp (Max)	Temp (Min)	RH (%) (Mor)	RH (%) (Eve)	Rainfall (mm)
Sucking pests					
Leafhoppers	-0.2228	-0.2101	-0.2707	-0.1706	-0.2041
Thrips	**0.4986 ***	**0.4645 ***	0.3941	0.4475	0.0382
Whitefly	-0.0882	0.1594	0.1640	0.2643	0.2076
Aphid	0.0341	0.1547	0.0270	0.1816	-0.0161
Pheromone trap catches					
H. armigera	**-0.5644 ***	**-0.5161 ***	-0.2775	-0.2948	-0.0925
S. liura	0.3391	0.3690	-0.0811	0.2646	0.3990
S. exigua	-0.4434	-0.1634	-0.0801	-0.0621	-0.0605
P. gossypiella	-0.2187	**-0.7997 ***	**-0.5991 ***	**-0.8559 ***	-0.3557

r_{Tab} (0.05,17_{df}) = 0.4555

by 51st standard week (30.50 moths/trap/week). In the pheromone traps, the catches of pink bollworm moths started during 38th standard week (1.00 moths/trap/week) and reached the peak during 47th standard week (5.50 moths/ trap/week) (Table 3).

Correlation studies between the sucking pests population and weather parameters indicated a significant and positive correlation between leafhopper population and temperature minimum (r= 0.6181)and relative humidity (evening)(r=0.5394).The present results are also confirm the findings of Laxman *et al.,* (2014) who reported that leafhopper population had a significant and positive correlation with relative humidity (evening). The present findings are also in conformity with Shera *et al.*, (2013), Selvaraj *et al.,* (2011) Shitole and Patel (2009), Kaur *et al.,* (2009) and Prasad *et al.,* (2008) who also reported significant and positive correlation between leafhoppers and relative humidity.The correlation between the other sucking pests and weather parameters tested was non significant.

However, among bollworms, the trap catches of *H. armigera* showed a positive and significant correlationwith temperature maximum(r=0.6089) whereas the trap catches of *Spodoptera exigua* showed a significant and positive correlation (r=0.4851)with relative humidity (evening). The trap catches of other bollworms did not show any correlation with the weather parameters tested (Table 4).

CONCLUSIONS

From the results of this study, it can be concluded that leafhoppers attained two peaks during the season in the test hybrid, DCH 32. The leafhopper population had a significant and positive correlation with temperature minimum and relative humidity (evening) whereas thrips showed a significant and positive correlation with both maximum and minimum temperatures. Moth catches of *H. armigera* had a significant but negative correlation with both maximum and minimum temperatures in one of the years of study and significantandpositive correlation with maximum temperature in the other year of study. Hence, it can be concluded that a long term study can only give complete picture of the dynamics of the insect pests.

Table 3. Population dynamics of insect pests of cotton and weather conditions at RARS, Nandyal during 2011-2012

Std. Week	Sucking pests/ 3 leaves			Natural enemies/plant		Bollworm trap catches				Abiotic factors				
	Leaf hoppers	Thrips	White flies	Lady birds	Spiders	*H. armigera*	*S. litura*	*S. exigua*	*P. gossypiella*	Temp. Max. (^{0} C)	Temp. Min. (^{0} C)	RH Mor. (%)	RH Eve. (%)	Rain fall (mm)
38(17thto 23rd Sep)	6.25	2.3	0.35	0.05	0.80	0.5	45.00	1.00	1.00	32.81	24.93	79.71	58.43	27.8
39(24thto 30th Sep)	4.85	0.7	0.80	0	0.15	4.80	21.00	1.40	1.00	34.83	24.58	68.00	52.78	0
40(1st to 7th Oct)	0	0	0	0	0.10	1.33	5.67	1.67	0.67	33.57	23.81	77.71	64.57	74.6
41(8th to 14th Oct)	4.8	0	1.50	0	0	1.40	2.20	2.00	1.00	33.21	24.6	78.42	65.28	14.2
42(15th to 21st Oct)	5.35	0	0	0	0	0.60	9.40	0.60	0.60	34.00	23.57	74.42	53.00	0
43(22nd to 28th Oct)	5.10	0	0.10	0	0	1.60	8.68	1.32	0.32	33.32	26.08	79.57	69.14	2.4
44(29th Oct to 4th Nov)	6.65	0	0.25	0.05	0	0.33	2.00	0.67	0.50	31.85	22.06	74.33	64.00	2
45(5th to 11th Nov)	4.10	0	0.45	0	0.05	1.00	15.00	2.40	1.00	32.77	18.65	62.71	53.28	0
46(12th to 18th Nov)	3.40	0	0.40	0	0.10	2.20	13.60	1.80	1.00	32.64	19.00	70.00	48.57	0
47(19th to 25th Nov)	3.85	0	0.40	0	0.05	0.75	26.25	2.50	5.50	30.69	20.94	79.70	62.00	13
48(26thNov to 2nd Dec)	2.40	0	0.50	0	0	0.50	22.50	1.00	0.50	30.25	22.43	81.50	69.50	13
49(3rdto 9th Dec)	3.25	0	1.00	0	0	0	14.75	1.25	2.50	32.05	20.54	79.14	56.28	0
50(10th to 16th Dec)	3.60	0	0.45	0.05	0	0.20	6.20	0.40	0.80	32.18	16.86	77.42	50.57	0
51(17th to 23rd Dec)	3.20	0	0.85	0	0	0.17	30.50	0.17	1.33	30.9	22.22	80.14	54.71	0
52(24th to 31st Dec)	2.15	0	0.95	0	0	1.20	27.20	1.60	2.40	31.00	17.04	82.05	45.33	0
1(1st to 6th Jan 2013)	1.75	0	0.50	0	0	1.17	1.67	0.67	2.17	32.70	19.82	77.28	51.14	0
2(7th to 13th Jan)	0.35	0	0.30	0	0	1.50	0.28	0.44	2.69	31.72	18.14	74.14	42.00	4.2
3(14th to 20th Jan)	0.40	0	0.60	0	0	0	1.00	0	0.20	31.06	13.74	73.00	23.71	0
4(21st to 27th Jan)	0.44	0	0.25	0	0	0.20	4.00	0.20	0	32.16	14.38	76.00	37.30	0

Table 4. Correlation between insect pests andweather parameters during 2011-2012

Pest	Temp. Max. (°C)	Temp. Min. (°C)	RH Mor. (%)	RH Eve. (%)	Rainfall(mm)
Sucking pests					
Leafhoppers	0.3299	**0.6181***	-0.0825	**0.5394***	-0.2195
Thrips	0.2498	0.3534	0.0566	0.0896	0.2303
Whitefly	-0.1534	-0.0169	0.1497	-0.0267	-0.2661
Pheromone trap catches					
H. armigera	**0.6089***	0.3528	-0.4264	0.1013	0.0149
S. liura	-0.1918	0.3133	0.2676	0.2460	0.0810
S. exigua	0.1854	0.3359	-0.1729	**0.4851***	0.2696
P. gossypiella	-0.3519	-0.0467	0.2359	0.0785	-0.0421

r_{Tab} (0.05,17_{df}) = 0.4555

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REFERENCES

Abbas. M.A. 2001. General Agriculture. Publication emporium . 2nd edition**,** Pakistan, 352.

Hameed, A., Shahzad, M. S., Ahmad, S. and Karar, H. 2015. Forecasting and modelling of *Helicoverpaarmigera* (Hub.) in relation to weather parameter in Multan, Punjab, Pakistan. *Pakistan J. Zool.*, **47**: 15-20.

Kaur, P., Singh, H. and Butter, N.S. 2009. Formulation of weather based criteria rules for the prediction of sucking pests in cotton (*Gossypiumhirsutum*) in Punjab. *Indian J. Agric. Sci.*, **79**: 375-80.

Laxman, P. ,Samatha, Ch and Sammaiah, Ch. 2014. Study on infestation of sucking insect pests on *Bt* cotton and non *Bt* cotton fields in Warangal- Telangana. International *J. Adv, Biol. Res.*, **4** : 172-77.

Prasad, N.V.V.S.D., Rao, N.H.P. and Mahalakshmi, M. S. 2008. Population dynamics of major sucking pests infesting cotton and their relation to weather parameters. *J. Cot. Res. Dev.,* **22** : 85-90.

Selvaraj, S., Adiroubane, D and Ramesh, V. 2011. Population dynamics of leafhopper, *Amrascadevastans*Distant in cotton and its relationship with weather parameters. *J.Ent.,* **8** : 476-83.

Shera, P. S., Vijay Kumar and Anand Aneja. 2013. Seasonal abundance of sucking insect pests on transgenic *Bt*cotton vis-à-vis weather parameters in Punjab, India. *Acta Phytopathologica et Entomologica Hungarica.,* **48** : 63–74.

Shitole, T.D. and Patel, I.S. 2009. Seasonal abundance of sucking pests and their correlation with weather parameters in cotton crop. *Pestology*, **33**: 38-40.

Shivanna, B.K., GangadharaNaik, B., Basavaraja, M. K., Nagaraja, R., KalleswaraSwamy, C.

M. &Karegowda, C. 2011. Impact of abiotic factors on population dynamics of sucking pests in transgenic cotton ecosystem. *Int. J. Sci. Nature*, **2** : 72-74

Vennila, S., Biradar, V.K., Sabesh, M and Bambawale, O.M. 2007a. Know your cotton insect pest whiteflies.*Crop Protection***,** Folder Series: 4

Vennila, S., Biradar, V.K., Sabesh, M and Bambawale, O.M. 2007b. Know your cotton insect pest thrips.*Crop Protection***,** Folder Series: 3

Yogesh and Rajnish Kumar, 2014. Monitoring *Helicoverpaarmigera* through pheromone trap catches under agroclimatic conditions of Eastern U.P. *Trends in Biosciences*, **7**:434-36.

Evaluation of spacing and spray schedule for management of bollworms in HDPS cotton

P. W. NEMADE, T. H. RATHOD, S. B. DESHMUKH, A. N. PASLAWAR, V. V. UJJAINKAR, V. V. DESHMUKH AND S. T. JAYLE

Cotton Research Unit, Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola - 444 104

E-mail: pwn.pdkv@gmail.com

ABSTRACT : The field experiment was conducted to evaluate the effective spray schedule for management in bollworms in high density planting system of cotton during *kharif* 2014. The experiment was laid out in FRBD with 3 replications. The non *Bt* cotton variety AKH 081 was sown in three different spacing 45x10 cm, 60x10 cm and 60x15 cm spacing (main treatments) and four insecticidal spray schedule as sub treatments. The experiment was conducted at Akola and Amravati research station. The results revealed that minimum larval population of bollworm (0.13) was observed in treatment S2M2 followed by S2M3. Interaction effect of spacing and modules were found non significant. Module 3 effectively managed larval population of bollworms whereas minimum green fruting bodies damage (2.69 %) was observed in treatment S2M2 at both the locations followed by S2M1. Maximum damage of green fruting bodies (20.83%) was noticed in S1M4 at both the location. Per cent open ball damage data was found significant but their interaction effect were non significant. Minimum open ball damage (2.44 %) was observed in treatment S2M2 schedule whereas maximum open ball damage (21.54 %) was recorded in S1M4 schedule. Data recorded on per cent loculi damage was found significant however their interaction effect found non significant. Minimum loculi damage (0.72 %) was observed in treatment S3M3 followed by S3M2. Maximum seed cotton yield was recorded in S2M2 (1403.27 kg/ha) whereas minimum was recorded in S1M4 (621.19 kg/ha). Thus, application of M3 schedule (flubendamide 480 SC @ 50ml/ac followed by indoxacarb 14.5 SC @ 100 ml/ac followed by fenvalerate 20 EC @ 160 ml/ac) was found superior in management of bollworms resulted in getting higher seed cotton yield and net monetary returns with spacing S2 (60 x 10 cm) in high density system of cotton.

Key words : Bollworms, HDPS, spacing, spray schedule

Cotton is an important crop of India and 60 million people derive their livelihood directly or indirectly from cotton production and its trade. The cotton crop provides fibre, food, feed, fuel, shelter and has a wide variety of medicinal and industrial uses (Siwach and Sangwan, 2012). With nearly 12 million hectares under the cotton crop, India ranks first in the world in respect of area and fourth in total production which has reached the level of 31 million bales (Mayee, 2011). But average productivity in India is quite low (523 kg lint/ha) as compared to worlds average productivity of 760 kg lint/ha (AICRP on Cotton, 2015). In India, cotton is cultivated under rainfed conditions in 60.0 per cent area. Productivity of cotton in these regions is low. Rainfall starts in June and recedes in September in majority of the rainfed cotton zone. Boll formation and retention get negatively affected in long duration varieties and hybrids due to low soil moisture, especially in shallow soils thus resulting in low yield. Major cotton producing countries like China, USA, Brazil, Uzbekistan and Australia continue to harvest high cotton yields through straight varieties adopting high plant population. Over the last few decades, these countries consciously developed dwarf, compact sympodial varieties amenable to high plant density (Venugopalan et al. 2013). The planting geometry is 8-10 cm distance between plants in a row with row to row distance at any of the spacing's at 30/45/60/75/90/100 cm. HDPS is more suitable to Indian conditions by using short duration varieties for improving productivity in rainfed region. Some early maturing compact genotypes have been identified for central region such as Suraj, PKV 081, NH 615 and AKA 07. But all these varieties are non Bt and management of bollworm is must to increase the productivity. Also many earlier workers reported that pest problem is higher in closer spacing than wider. Therefore, the present study was planned to find out suitable spacing and effective insecticidal module for the management of bollworms in high density planting system of cotton in rain fed condition of Vidarbha region.

MATERIALS AND METHODS

The experiment was laid out in FRBD with three replications. The cotton variety AKH 081 was sown at Akola and Amravati location in *kharif* 2014 and regular agronomic practices were followed. Three different spacing's 45 x 10 cm, 60 x 10 cm and 60 x 15 cm along with four different insecticidal spray scheduled were evaluated in this study. The treatments details are as follows:

	Main treatments (Spacing) (cm)
S1 -	45 x 10
S2 -	60 x 10
S3 -	60 x 15
	Sub treatments (Management of bollworm)
M1 -	Quinalphos 25 EC@ 400ml/ ac > Spinosad (45% SC) @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M2 -	Flubendamide 480 SC @ 50ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M3 -	Flubendamide 480 SC @ 50ml/ac > Spinosad (45% SC) @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M4 -	Control

Treatment combinations are - T1- S1M1, T2 - S1M2, T3 - S1M3, T4 - S1M4, T5 - S2M1, T6 - S2M2, T7 - S2M3, T8 - S2M4, T9 - S3M1, T10 - S3M2, T11 - S3M3, T12 - S3M4.

The observations on larval population of *H. armigera* and green fruiting bodies damage were recorded after each treatment spray on randomly selected 5 plants from each net plot on whole plant. The observation on open boll damage and loculi damage by bollworms was recorded at the time of harvest. The picking wise yield of seed cotton was recorded.

RESULTS AND DISCUSSION

a) Effect on larval population of bollworm:

Akola: The data recorded on larval population of bollworm at Akola location was found significant over control. Minimum larval population of bollworm (0.13) was observed in treatment S2M2 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac followed by S2M3 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac). However, maximum larval population of bollworm (0.87) was recorded in S1M4 which consisted 45 x 20 cm spacing without any insecticidal application. Interaction effect of spacing and modules were found non significant. Module 3 (application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) effectively managed larval population of bollworms in HDPS cotton. (Table 1).

Amravati: The data recorded (Table 1) on larval population of bollworm at Amravati location was found significant over control. Minimum population of bollworm (0.04) was observed in treatment S2M3 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) followed by S2M2 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac). Maximum larval population of bollworm (0.53) was recorded in S1M4 i.e. control treatment having 45 x 10 cm spacing. Interaction effect of spacing and modules were found non significant.

Table 1. Effect of spacing, module and its interaction on larval population of bollworm

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M 1	0.44(0.97)	0.24(0.86)	0.33(0.91)	**1.01(0.91)**	0.29(0.89)	0.22(0.85)	0.13(0.79)	**0.64(0.84)**
M 2	0.47(0.98)	0.13(0.80)	0.27(0.88)	**0.87(0.88)**	0.24(0.86)	0.16(0.81)	0.18(0.82)	**0.58(0.83)**
M 3	0.33(0.91)	0.22(0.85)	0.31(0.90)	**0.86(0.88)**	0.22(0.85)	0.04(0.74)	0.29(0.88)	**0.55(0.82)**
M 4	0.82(1.15)	0.71(1.10)	0.67(1.08)	**2.20(1.11)**	0.53(1.01)	0.31(0.90)	0.40(0.94)	**1.24(0.95)**
MEAN	**2.06(1.00)**	**1.30(0.90)**	**1.58(0.94)**		**1.28(0.90)**	**0.73(0.82)**	**1.00(0.86)**	
	Spacing	**Module**	**Spacing x Module**	**Spacing**	**Module**	**Spacing x Module**		
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.03	0.03	0.05		0.02	0.02	0.04	
CD (p=0.05)	0.07	0.09	0.15		0.06	0.07	0.11	
CV (%)	**9.23**				**8.78**			

Figures in parenthesis are square root (x+0.5) transformed values

b) Effect on green fruiting bodies (GFB) damage:

Akola: Minimum green fruting bodies damage (2.69 %) was observed in treatment S2M2 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac at Akola location followed by S2M1 (Quinalphos 25 EC@ 400ml/ ac > Spinosad 45%SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) however, their effcet were found non significant. Maximum damage of green fruting bodies (20.83%) was noticed in S1M4 *i.e.* control treatment having 45 x 10 cm spacing. (Table 2).

Amravati: Treatment S3M2 which consisted 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac recorded minimum green fruting bodies damage (1.45%) at Amravati location however, their effcet were found non significant. Maximum damage of green fruting bodies (12.88%) was observed in S1M4 i.e. control treatment having 45 x 10 cm spacing. (Table 2).

Table 2. Effect of spacing, module and its interaction on per cent GFB damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	MEAN
M 1	6.11(14.28)	2.97(9.87)	3.84(11.17)	**4.31(11.77)**	3.81(11.15)	1.65(7.23)	1.83(6.32)	**2.43(8.23)**
M 2	6.56(14.82)	2.69(9.36)	4.21(11.70)	**4.49(11.96)**	4.10(11.67)	2.18(8.43)	1.45(6.88)	**2.58(8.99)**
M 3	4.32(11.93)	3.05(9.70)	4.91(12.78)	**4.09(11.47)**	4.49(12.03)	1.53(7.08)	1.95(8.02)	**2.66(9.04)**
M 4	20.83(27.13)	18.35(25.21)	17.96(25.06)	**19.05(25.84)**	12.88(21.01)	10.70(19.07)	10.45(18.86)	**11.34(19.65)**
MEAN	**9.46(17.04)**	**6.77(13.56)**	**7.73(15.18)**		**6.32(13.96)**	**4.02(10.45)**	**3.92(10.02)**	
	Spacing	**Module**	**Spacing x Module**	**Spacing**	**Module**	**Spacing x Module**		
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.54	0.63	1.09		0.60	0.69	1.20	
CD (p=0.05)	1.59	1.84	3.18		1.76	2.03	3.52	
CV (%)	**12.32**				**18.13**			

Figures in parenthesis are arc sine transformed values

c) Effect on open ball damage:

Akola: Per cent open ball damage data recorded at Akola location was found significant but their interaction effect were non significant. Minimum open ball damage (2.44 %) was observed in treatment S2M3 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum open ball damage (21.54 %) was recorded in closer spacing *i. e.* S1M4 treatment (Table 3).

Amravati: Data of effect of spacing and module on per cent open ball damage noted at Amravati location was found significant however their interaction effect found non significant. Minimum open ball damage (1.37%) was observed in treatment S3M3 *i.e.* in 60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum open ball damage (18.80%) was recorded in S1M4 treatment (Table 3).

d) Effect on per cent loculi damage

Akola: Data recorded at Akola location on effect of spacing and modules on per cent loculi damage was found significant however their interaction effect found non significant. Minimum loculi damage (0.72 %) was observed in treatment S3M3 (60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/

Table 3. Effect of spacing, module and its interaction on per cent open bolls damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M1	5.54(13.55)	4.85(12.70)	3.57(10.84)	**4.65(12.36)**	5.80(13.88)	3.82(11.25)	3.24(10.33)	**4.29(11.82)**
M2	4.61(12.38)	2.80(9.62)	2.49(9.02)	**3.30(10.34)**	4.63(12.09)	3.36(10.54)	3.62(10.94)	**3.87(11.19)**
M3	4.17(11.56)	2.44(8.96)	2.55(9.10)	**3.05(9.87)**	4.52(12.24)	2.88(9.71)	1.37(5.48)	**2.92(9.14)**
M4	21.54(27.65)	20.38(26.83)	18.84(25.73)	**20.25(26.74)**	18.80(25.69)	16.14(23.65)	15.44(23.14)	**16.79(24.16)**
MEAN	**8.97(16.29)**	**7.62(14.53)**	**6.86(13.67)**		**8.44(15.97)**	**6.55(13.79)**	**5.92(12.47)**	
	Spacing	**Module**	**Spacing x Module**		**Spacing**	**Module**	**Spacing x Module**	
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.39	0.45	0.78		0.58	0.67	1.16	
CD (p=0.05)	0.14	1.32	2.29		1.70	1.96	3.40	
CV (%)	**9.12**				**14.26**			

Figures in parenthesis are arc sine transformed values

Table 4. Effect of spacing, module and its interaction on per cent loculi damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M1	1.65(1.26)	1.21(1.10)	0.90(0.95)	**1.25(1.10)**	1.66(1.28)	0.96(0.98)	0.81(0.90)	**1.14(1.05)**
M2	1.32(1.15)	1.19(1.07)	0.82(0.89)	**1.11(1.04)**	1.35(1.11)	1.10(1.04)	0.90(0.94)	**1.12(1.03)**
M3	1.49(1.20)	0.86(0.90)	0.72(0.84)	**1.02(0.98)**	1.44(1.19)	0.72(0.85)	0.47(0.55)	**0.88(0.86)**
M4	5.39(2.32)	5.99(2.44)	6.08(2.46)	**5.82(2.41)**	6.58(2.56)	4.76(2.18)	5.54(2.32)	**5.63(2.35)**
MEAN	**2.46(1.48)**	**2.31(1.38)**	**2.13(1.28)**		**2.76(1.54)**	**1.89(1.26)**	**1.93(1.18)**	
	Spacing	**Module**	**Spacing x Module**		**Spacing**	**Module**	**Spacing x Module**	
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.06	0.07	0.11		0.07	0.09	0.15	
CD (p=0.05)	0.17	0.19	0.33		0.22	0.25	0.44	
CV (%)	**14.22**				**19.42**			

Figures in parenthesis are square root transformed values

ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) followed by S3M2 *i.e.* 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac. However, maximum loculi damage (6.08 %) was recorded in S3M4 treatment *i.e.* 60 x 15 cm spacing without any insecticidal application (Table 4).

Amravati: Per cent loculi damage due to effect of spacing and modules was found significant at Amravati location however, their interaction effect found non significant. Minimum loculi damage (0.47%) was observed in S3M3 *i.e.* 60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum loculi damage (6.58%) was recorded in S1M4 treatment which is control plot having 45 x 10 cm spacing(Table 4).

e) Effect on seed cotton yield : Maximum seed cotton yield was recorded in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac (1501.63 kg/ha) *i.e.* in S2M2 treatment followed by S3M2 (1450.00 kg/ha) *i.e.* 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas minimum was recorded in S1M4 (643.24 kg/ha)

Table 5. Effect of spacing, module and its interaction on Seed Cotton Yield (Kg/ha)

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M 1	821.89	1178.43	1298.15	**1099.49**	816.45	1011.44	1079.26	**969.05**
M 2	1015.79	1501.63	1450.00	**1322.47**	986.38	1304.90	1187.04	**1159.44**
M 3	959.42	1243.13	1358.89	**1187.15**	966.23	1045.10	1132.96	**1048.09**
M4	643.24	723.85	861.85	**742.98**	599.13	675.82	648.52	**641.15**
MEAN	**860.09**	**1161.76**	**1242.22**		**842.04**	**1009.31**	**1011.94**	
	Spacing	**Module**	**Spacing xModule**	**Spacing**	**Module**	**Spacing xModule**		
F test	**SIG**	**SIG**	**SIG**		**SIG**	**SIG**	**NS**	
SE (m)+-	37.31	43.08	74.62		38.42	43.19	75.82	
CD (p=0.05)	109.41	126.34	218.83		110.70	126.67	219.39	
CV (%)	**11.88**				**13.58**			

at Akola location (Table 5).

Similar trend was also observed at Amravati location recording maximum seed cotton yield in 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac (1304.90 kg/ha) and minimum in control treatment having 45 x 10 cm spacing (599.13 kg/ha) (Table 5).

f) Net profit and ICBR : At Akola location higher net profit was recorded in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac treatment (S2M2) (Rs 28097.15/ha) followed by S3M2 (Rs 19356.83/ha) which consisted 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas lowest was recorded in S1M1 (Rs 4811.61/ha) treatment. However, maximum ICBR (1:7.7) was recorded in S2M2 *i.e.* 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac followed by S2M3 (1:6.0) (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) (Table 6).

Paslawar *et al.,* (2013) reported that AKH-081 an early and dwarf variety at narrow spacing of 45 x 10 cm showed highest plant height, higher LAI, highest seed cotton (3218 kg/ha), lint and biological yield with highest gross monetary (Rs 125502) and net monetary returns (Rs 86258) with cost benefit ratio of 3.18. However, square dropping and incidence of bollworm complex was more in narrow spacing. Venugopalan *et al.,* (2013) tested several compact varieties and among them AKH 081, NH 615, Suraj, Anjali KC3 (*G. hirsutum*) and AKA7, JK5 and HD123 (*G. arboreum*) planted at 60 x 10 cm, 45 x 15 cm and 45 x 10 cm under rainfed conditions. Further they stated that, by

Table 6 Effect of spacing, module and its interaction and net profit & ICBR at Akola.

Sr. No.	Treatment details	Yield (kg/ha)	Increased yield	Akola Plant Prot. cost (Rs)	Net profit (Rs)	ICBR
T_1	S1M1	821.8919	178.65	2245	4811.61	1: 1.2
T_2	S1M2	1015.791	372.55	3875	10840.62	1: 2.1
T_3	S1M3	959.4186	316.18	2025	10463.92	1: 3.3
T_4	S1M4	643.2435	0.00			
T_5	S2M1	1178.429	454.57	2898	15057.68	1: 3.7
T_6	S2M2	1501.631	777.78	2625	28097.15	1: 7.7
T_7	S2M3	1243.135	519.28	2025	18486.56	1: 6.0
T_8	S2M4	723.8546	0.00			
T_9	S3M1	1298.147	436.30	2898	14335.69	1: 3.5
T_{10}	S3M2	1449.999	588.15	3875	19356.83	1: 3.9
T_{11}	S3M3	1358.888	497.04	2025	17607.94	1: 5.7
T_{12}	S3M4	861.851	0.00			

• Standard spray volume - 500 l water/ha. • Labour charges for spraying - 5 labour/ha @ Rs 180/day for spraying. • 3 Knapsack spray pump rent - @ Rs 25/day = 75 Rs/ha. • Av. market price of cotton - @ Rs 3950/q (MSP 2014-15) • Quinolphos 20 SP @ Rs 370/l • Spinosad 45 SC @ Rs 1123/75 ml • Indoxacarb 14.5 SL @ Rs 140/100 ml • Flubendamide 5 SC @ Rs 682/50 ml • Fenvalerate 20 EC @ Rs 400/l increasing the plant population from 50,000 plants/ha to 1.5 to 2.0 lakh plants/ha, it is possible to realize 1800-2000 kg/ha seed cotton/ ha with the above varieties on marginal soils under rainfed conditions with minimum inputs which is more than twice the average yield of Vidarbha. Ganvir *et al.,* (2013) reported that the spacing 60 x 10 cm produced significantly higher seed cotton yield, gross monetary returns and net monetary returns than spacing 60 x 30 cm and it was *at par* with 60 x 15 cm but benefit cost ratio was higher in 60 x 15 cm of AKH 081. Ahuja *et al.,* (2013) evaluated *G. arboreum* genotypes for HDPS in northern India and on the basis of two years data reported that there was in general higher yield for 67.5 x 20 cm spacing with an increase in yield range of 3 to 8 q/ha (10.1 to 27.8% increase) over normal spacing of 67.5 x 30 cm except for CISA 310 (67.5 x 10 cm, 32.2%).

CONCLUSION

Application of flubendamide 480 SC @ 50ml/ac followed by indoxacarb 14.5 SC @ 100 ml/ac followed by fenvalerate 20 EC @ 160 ml/ ac in 60 x 10 cm spacing was found superior in getting higher seed cotton yield and net monetary returns in High Density Planting System of cotton.

REFERENCES

Ahuja, S. L., Monga D., Meena, R. A., Rishi Kumar and Neha Saxena 2013. Evaluation of *G. arboreum* cotton genotypes for High Density Planting Systems in northern India. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : 9.

Ganvir, S. S., Khargkharate, V. K., Ghanbahadur, M. R., Tamgadge, J. B. and Nage, S. M. 2013. Effect of high density planting, nutrient management and In-Situ moisture conservation on productivity of hirsutum cotton. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : 85.

Mayee, C.D. 2011. Indian Cotton Welcomes WCRC-5. *World Cotton Research Conference.* The Renaissance Mumbai Hotel and Conservation Center, India: 1-6.

Paslawar, A. N., Patil B. R., Ingole O.V., Nemade P.W. and Deotalu, A. S. 2013. High Density Planting System for AKH-081 and its influence on Growth, Yield and Economics under rainfed cultivation. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch :74.

Siwach, S. S. and Sangwan, R. S. 2012. Performance of hybrids produced by different systems for yield and quality in *Gossypium hirsutum* L. Silver Jubilee International Symposium on *"Global Cotton Production Technologies vis-à-vis Climate Change"* 10-12 October, 2012, CCS HAU, Hisar :157-162.

Venugopalan, M. V., Blaise D., Tandulkar, N. R. and Shubhangi Lakde. 2013. HDPS- A promising option for Rainfed Cotton. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : L-3.

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Status of whitefly (*Bemisia tabaci* Gennadius) population on *Bt* cotton in Marathwada region of Maharashtra under changing climate

P.R. ZANWAR, A.G. BADGUJAR, B.B. BHOSLE AND S.T.SHINDE

Department of Agril. Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani -431 402

E-mail : pr_zanwar@rediffmail.com

ABSTRACT : The severity of whitefly population is becoming a major concern to transgenic cotton farmers. Keeping this in view scientific survey of whitefly (*Bemisia tabaci* Gennadius) incidence on *Bt* cotton was carried out from last five years (2009-2010 to 2013-2014), in six major cotton growing districts (*viz.,* Parbhani, Hingoli, Nanded, Jalna, Aurangabad and Beed) of Marathwada region of Maharashtra under Crop Pest Surveillance and Advisory Project (CROPSAP) by using ICT tools and total 171 ETL based advisories were issued twice in a week to monitor the pest. On the basis of taluka wise roving survey, the district wise mean data was calculated and showed that during 2009-2010, maximum incidence of whitefly (per three leaves) was recorded in Hingoli (5.92) followed by Jalna (5.20) and minimum in Beed (1.40) district. Similarly during 2010-11, the population was highest in Hingoli (8.72) followed by Jalna (7.72) and lowest in Beed (1.36). During 2011-2012, it was more in Hingoli district (4.20) followed by Nanded (3.48) and minimum in Beed (0.76). During 2012-2013, severe infestation of whiteflies (5.52) observed in Hingoli district followed by Jalna (4.84). Whereas during 2013-2014, Jalna district recorded highest population of whitefly (6.52) followed by Hingoli (5.44) and Parbhani (4.00). The five years data indicated that the severity of whitefly incidence was more during 2010-2011 while it was minimum during 2011-2012. It is observed that Hingoli and Jalna districts of Marathwada are identified as hotspots for cotton whitefly.

Key words: District, incidence, population, survey, whitefly

Cotton is the important cash crop of Marathwada region of Maharashtra state . Cotton is known as one of the most important commercial crop playing a key role in economical, social and political status of the world. In India, more than 60 million people are engaged in cultivation, processing, marketing and other cotton related activities. Cotton is a predominant raw material of Indian textile industry which contributes for more that 14 per cent of the annual value addition of industrial production and more than 30 per cent of the total export with 4 per cent of its gross domestic product. *Bt* cotton technology which was introduced in 2002, has played major role in cotton production and productivity in India. However, sucking pests *viz.,* jassids,thrips and whiteflies are posing a threat to cultivation of *Bt* cotton under climate change. The whitely (*Bemesia tabaci* Gennadious) is assuming a status of major sucking pest on *Bt* cotton. The whitefly may cause 60.2-99.7 per cent loss in seed cotton(Singh *et al.*, 1983). The constant monitoring of whitefly population on *Bt* cotton was carried out through roving survey to know the seasonal and peak incidence of whitefly under agro climatic conditions of Marathwada . The study will be useful to undertake timely management practices against whitefly to the farmers of all the districts of Marathwada region.

MATERIALS AND METHODS

The talukawise survey was carried out in six major cotton growing districts *viz.,* Parbhani, Nanded, Hingoli, Beed, Jalna and Aurangabad of Marathwada to record the status of whitefly under “Crop Pest Surveillance and Advisory Project (CROPSAP)” during 2009-2010 to 2013-2014. During the survey eight fields from each taluka were selected and the incidence of whiteflies were recorded from 10 randomly selected plants from each field. Population of whitefly was recorded from three leaves (bottom, middle and top) of each plant. Average population of whiteflies were worked out for interpretation of data . ETL based advisories were disseminated to the farmers during the study period.

RESULTS AND DISCUSSION

The data on population dynamics of whiteflies during 2009-2010 presented in Table 1 and revealed that in Parbhani district first incidence of whitefly was noticed in 31st MW and it was increased upto 39th MW and attained its peak (7.40). There after it was decreased upto 0.56 in 46 MW. The whiteflies infestation fluctuates in between 0.30 to 7.40 with a average of 3.48. Whereas in Hingoli district whiteflies incidence was noticed in 32nd MW and attains its peak 38th MW thereafter whitefly activity was constant up to end of season with a average of 5.92. In Nanded district whitefly activity was noticed from start of season and it increased from 36th MW and attains its peak in 38th MW. Thereafter it goes on decreasing in the end of season. The whitefly population fluctuates in between 0.04 to 5.96 with a average of 3.24. Similarly in Jalna district the activity of whiteflies was recorded from start of season and it ranges in between 0.10 to 10.40. Infestation starts from 30th MW and attains its peak with severity in 42nd and 43rd MW (10.40 and 10.12) and it remains active throughout season with an average of 5.20. In Aurangabad district comparatively less infestation of whiteflies was

Table 1. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada during 2009-2010

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
30	0	0	0.04	0.1	0	0
31	0.3	0	0.08	0.14	0.02	0
32	0.12	0.15	0.04	0.38	0.6	0
33	0.25	0.2	0.15	0.86	0.36	0
34	0.27	0.82	0.4	1.6	0.8	0.2
35	1.5	3.5	1.25	2.15	1.2	0.18
36	4.84	5.35	3.86	4.12	1.23	0.2
37	6.32	7.54	4.1	5.52	1.44	0.6
38	7.15	9.2	5.96	6.3	1.44	0.6
39	7.4	9.13	5.42	6.31	1.75	0.84
40	7.32	8.85	5.3	7.9	1.86	0.9
41	6.3	7.45	4.8	9	1.9	1.02
42	4.58	7.35	5.32	10.4	2.03	1.66
43	3.75	6.8	4.00	10.12	2.30	3.04
44	3.2	6.51	4.14	8.7	1.48	3.08
45	1.85	6	4.05	8.8	1.8	1.8
46	0.56	4.24	3	6	1.12	1.65
Mean	**3.48**	**5.92**	**3.24**	**5.20**	**1.44**	**1.4**

noticed. The first incidence was recorded in 31st MW and it attains its peak in 43rd MW (2.30) and it ranges in from 0.02 to 2.30 with a average of 1.44. Whereas in Beed district the infestation starts from 34th MW and its peak activity noticed during 43rd and 44th MW with a average of 1.4.

The data on population dynamics of whitefly during 2010-2011 revealed that(Table 2) in Parbhani district, the population of whiteflies was noticed during 28th MW. The peak population was recorded in 44th MW (14.16). The population ranged in between (0.04 to 14.16) though out the season whiteflies population was above ETL. From 41st MW to 46th MW. With a average of 5.24. In Hingoli district population of whiteflies was noticed in 30th MW and gradually increasing up to 39th MW and attains its peak (21.32) the it goes down decreasingly. But it was above ETL from 38th MW to 47th MW. The population ranged in between, 0.28 to 21.32 with a average population of 8.72. In Nanded district the infestation was recorded in 29th MW (0.12) and population of whiteflies was constant from 38th MW to 44th MW. The population ranges from 0.12 to 9.96 with average of 4.68. In Jalna district the whiteflies incidence was noticed in 28th MW and attains its peak in 43rd MW (15.60).The whiteflies population fluctuates in between 0.04 to 15.60 with a season average of 7.72 whiteflies / 3 leaves. The whitefly infestation was above ETL from 38th MW to 47th MW.

In Aurangabad district incidence of whiteflies was noticed in 28th MW and reaches a maximum population of 5.44 in 41st MW with a average of 2.6.In Beed district the incidence of whiteflies was noticed in 29 MW (0.12) and reaches its highest at 3.28 in 39th MW and population decreasing gradually (Table 2).

The data presented (Table 3) represents population of whiteflies during 2011-2012 and

Table 2. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2010-2011

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
28 MW	0.04	0.00	0.00	0.04	0.28	0.00
29 MW	0.04	0.00	0.12	0.24	0.32	0.12
30 MW	0.12	0.28	0.56	0.32	0.64	0.32
31 MW	0.28	0.80	0.92	0.72	0.88	0.32
32 MW	0.36	1.36	1.08	1.12	1.08	0.32
33 MW	0.68	2.40	1.80	1.56	1.36	0.36
34 MW	0.92	2.76	2.60	1.72	1.56	0.56
35 MW	1.00	3.96	3.12	2.40	1.56	1.00
36 MW	1.56	4.72	3.88	3.08	1.96	1.00
37 MW	1.76	7.40	5.16	7.40	2.28	1.16
38 MW	2.76	12.76	7.48	10.64	3.80	1.48
39 MW	4.64	21.32	9.96	10.92	3.12	3.28
40 MW	9.56	20.08	9.04	14.08	4.92	3.08
41 MW	12.36	16.52	9.00	14.92	5.44	2.88
42 MW	11.56	12.92	9.04	15.00	5.36	2.76
43 MW	12.20	15.76	8.44	15.60	4.64	2.48
44 MW	14.16	13.32	9.56	14.48	4.16	2.04
45 MW	12.20	12.68	5.40	14.84	3.68	1.96
46 MW	11.64	12.28	3.60	12.44	2.64	1.20
47 MW	7.32	13.40	2.92	12.96	2.32	0.76
Mean	**5.24**	**8.72**	**4.68**	**7.72**	**2.60**	**1.36**

Table 3. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2011-2012

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0.12	0.04	0	0	0
31	0.04	0.12	0.12	0	0.24	0.08
32	0.24	0.2	1.04	0.24	0.56	0.04
33	0.56	0.84	1.68	0.44	0.72	0.08
34	1.52	1.56	1.48	0.88	0.92	0.28
35	0.92	2.04	2.12	1.64	0.76	0.28
36	1.4	3.76	3.12	2.08	0.88	0.44
37	1.48	6.24	4.12	2.24	1	0.44
38	1.84	6.84	4.56	2.44	1.52	0.68
39	2.16	6.88	4.96	2.6	1.76	0.8
40	2.04	7.56	5.8	3.32	1.84	0.88
41	2.36	8.12	5.72	3.56	1.88	0.96
42	2.36	8.56	6.2	3	1.84	1.64
43	2.32	8	6.96	2.84	1.8	1.84
44	2.56	7.68	6.84	2.76	1.8	1.68
45	1.92	5.8	6	2.88	1.56	1.6
46	2.04	5.28	5.08	3.28	1.36	1.48
Mean	**1.36**	**4.20**	**3.48**	**1.92**	**1.12**	**0.76**

revealed that in Parbhani district incidence of whiteflies was noticed in 31st MW and reaches its maximum in 44th MW (2.56). The population of whiteflies was fluctuates in between 0.04 to 2.56 whiteflies /leaf with a average of 1.36. In Hingoli district, the incidence was started from 30th MW and attains its peak in 42nd MW then its goes down decreasingly. The population of whiteflies ranges from 0.12 to 8.56 with a average of 4.2. Similarly in Nanded district the population fluctuates in between 0.04 to 6.96 with a average of 4.68 where as in Jalna district whitefly incidence was noticed in 32nd MW and reaches its peak (3.56) in 41st MW. During the season, population of whiteflies fluctuates in between 0.24 to 3.56 with average of 1.92. In Aurangabad district the infestation starts from 31st MW and reaches its peak in 41st MW with a average of 1.12.

The trend of incidence was constant from 36 MW to end of season i.e. 46th MW. Similarly in Beed district the infestation starts from 31st MW and attains its peak in 43rd MW with average of 0.76. During the year infestation was competitive more in Hingoli district.

The data (Table 4) revealed that during 2012-2013 in Parbhani district. The population of whiteflies ranged in between 0.28 to 7.40. The first incidence was noticed in 31st MW and attains its peak in 39th MW. There after population decreases gradually up to 46th MW. Whereas in Hingoli district infestation starts whereas from 33rd MW and it goes gradually increasing up to 39th MW and attains its peak (9.76) there after it goes on decreasing gradually. The average incidence of whiteflies was 5.52. In Nanded district the population fluctuates in between 0.08 to 6.20. The infestation starts from 31st MW and attains its peak in 38th MW thereafter it goes on decreasing with a average mean of 3.52 where as in Jalna district infestation starts from 30th MW and goes on increasing up to 42nd MW and attains its peak (8.92) thereafter it goes on decreasing. The population fluctuates in between 0.08 to 8.92 with a mean of 4.84.

In Aurangabad district infestation noticed in 32nd MW, it was moderately increased and constant throughout the season with a peak in 42nd MW (1.84). The average incidence of whiteflies was 1.08 whereas in Beed district infestation starts from 34th MW and it fluctuates up to 40th MW thereafter it goes on increasing up to 43rd and 44th MW and attains its peak (3.16) and thereafter goes down decreasing up to 46th MW with a season average of 1.36. In Parbhani district the activity of whiteflies started from 35th MW to 46th MW. Peak activity of whiteflies was observed during 39th MW (13.8/3 leaves).

The mean seasonal incidence of whiteflies in Parbhani during 2013-14(Table 5) was 6.36/3 leaves. Incidence of whiteflies in Hingoli district peaked in 41st MW (11.28/3 leaves) the population of whiteflies ranged from 6 to 11.26 / 3 leaves during different MW. The mean seasonal incidence of whiteflies in Nanded district was lower as compared to other districts *i.e.* 1.92 leaves. The highest population of whiteflies / 3 leaves was observed during 42 MW (2.48 / 3 leaves). In Jalna district the peak activity of whiteflies was recorded during 40th MW (12.80 / 3 leaves). The mean seasonal population of whiteflies on cotton in Jalna district was highest (9.48 / 3 leaves) as compared to other districts. The population of whiteflies valued between 3.16 and 12.80/3 leaves of cotton.

The present findings are similar with the findings of Rote and Puri (1991) and Patel (1992) who reported that *B.tabaci* was at peak during 2nd week of October to 3rd week of November. Daware *et al.,* (2003) reported first appearance of whiteflies from first week of August (31st MW) and peaked in first week of October to second week of November (40th -46th MW). Prasad *et al.,* (2008) observed that the peak incidence of whiteflies was from 44th to 48th standard week

Table 4. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2012-2013

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
30	0.00	0.00	0.00	0.08	0.00	0.00
31	0.28	0.00	0.08	0.12	0.00	0.00
32	0.12	0.00	0.04	0.36	0.08	0.00
33	0.16	0.24	0.16	0.84	0.32	0.00
34	0.16	1.28	0.44	1.52	0.60	0.32
35	0.96	3.84	1.00	2.08	0.92	0.20
36	4.84	5.68	4.32	4.04	1.16	0.52
37	6.08	8.00	6.00	5.48	1.36	1.12
38	7.08	9.60	6.20	6.28	1.56	1.72
39	7.40	9.76	5.44	6.20	1.68	1.84
40	7.32	9.56	5.32	7.80	1.76	1.40
41	5.24	7.96	5.00	8.60	1.80	1.88
42	3.72	8.20	5.04	8.92	1.84	2.80
43	3.12	7.40	4.40	8.76	1.60	3.16
44	2.00	6.52	4.60	8.20	1.48	3.16
45	1.20	6.04	4.16	7.08	1.36	2.72
46	0.56	4.24	4.16	5.76	1.12	2.48
Mean	**3.12**	**5.52**	**3.52**	**4.84**	**1.08**	**1.36**

Table 5. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada during 2013-2014

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
35	1.76	6.04	1.16	3.16	0.92	0.56
36	2.32	6.04	1.84	4.92	1.04	0.88
37	3.44	7.56	1.56	12.52	1.04	3.24
38	10.16	8.72	1.76	11.28	1.20	1.20
39	13.80	11.16	1.96	13.12	1.40	1.28
40	13.00	11.12	2.44	12.80	1.52	3.24
41	13.56	11.28	2.00	12.48	1.56	4.32
42	8.96	10.28	2.48	12.20	1.64	4.12
43	4.52	9.12	2.12	10.32	1.36	4.36
44	2.72	9.56	1.96	8.16	1.28	4.72
45	1.44	7.52	1.96	6.84	1.24	3.04
46	0.52	6.00	1.76	5.72	1.08	2.28
Mean	**6.36**	**8.72**	**1.92**	**9.48**	**1.28**	**2.76**

(November). Mohapatra (2008) reported the peak population of *B.tabaci* attained during 44th standard week (October 29 to November 04). Parsai and Shastry (2009) observed the incidence of whitefly from 33rd – 48th SMW with its maximum incidence (21.1-31.1/3 leaves) during 41st SMW. The findings are also supported with those of Sharma *et al.,* (2004) and Pawar *et al.,* (2008). The incidence of whitefly was more in second fortnight of September to first fortnight of October in all the districts of Marathwada and this period should be considered as important to undertake effective the whitefly management practices .

REFERENCES

Daware, D.G., Kurtadikar, J.S., Lavekar, R.C. and Bhosle, B.B. 2003. Achievements in insect pest management in cotton. *State level seminar on pest management for sustainable Agriculture* February 6-7, 2003 MAU, Parbhani: 4-6.

Mohapatra, L.N. 2008. Population dynamics of sucking pests in *hirsutum* cotton and influence of weather parameters on its incidence in western Orissa. *J. Cotton Res. Dev.*, **22** : 192-94.

Parsai, S.K. and Shastry, P.P. 2009. Seasonal incidence of key pests and their natural enemies on cotton. National Symposium on "*Bt-cotton: Opportunities and Prospects*" at ICCR, Nagpur, November 17-18, 2009 : 125-26.

Patel, J.R. 1992. Integrated pest Management in Cotton Hybrid-6. *Ph.D. Thesis* GAU, Anand.

Pawar, A.V., Chavan, S.J., Bhute, N.K. and Kadam, D.R. 2008. Population dynamics of sucking pest complex on cotton at Marathwada region of Maharashtra. *J. Plant Prot. Environ.*, **5** : 150-53.

Prasad, N.V.V.S.D., Rao, N.H.P. and Mahalakshmi, M.S. 2008.. Population dynamics of major sucking pests infesting cotton and their relation to weather parameters. *J. Cotton Res. Dev.*, **22** : 85-90.

Rote, N.B. and Puri, S.N. 1991. Population dynamics of whitefly *B. tabaci* on cotton and its relationship with weather parameters. *J. Cotton. Res. Dev.,* **5** : 181-89.

Sharma, P.D., Jat, K.L. and Takar, B.L. 2004. Population dynamics of insect pests on American cotton (*Gossypium hirsutum* L.) in Haryana. *J. Cotton Res. Dev.*, **18** : 104-06.

Singh, J.,**Butter, N.S. and Madan,V.K.1983**. Assessment of losses due to whitefly, *B. tabaci* in *hirsutum* cotton. *Indian J.ent.* Spl.Issue-**2** : 362-66.

Field performance of *Bt* cotton hybrids against major pests under unprotected conditions in Andhra Pradesh

N.V.V.S. DURGA PRASAD, M.S. MAHALAKSHMI, Y.SATISH, K.V.SIVA REDDY, B.SREELAKSHMI, V.CHENGA REDDY AND E.NARAYANA

Acharya N. G. Ranga Agricultural University Regional Agricultural Research Station, Lam, Guntur -522034

E-mail: nemanidp@yahoo.com

ABSTRACT : A field study was conducted to evaluate 59 *Bt* cotton hybrids along with check hybrid (Jaadoo) against sucking pests at RARS, Lam during 2013-14. Among the different sucking pests, leafhopper incidence was moderate to high, where as incidence of aphids and whiteflies was low to medium and the thrips incidence was very low. The incidence of leaf hoppers was ranged from 2.3 to 11.3/ 3 leaves, while whiteflies were ranged from 0.9 to 13.4/3 leaves with significant differences among the different hybrids. The incidence of aphids was ranged from 1.6 to 20.9/ 3 leaves with significant differences, while it was from 0.1 to 2.4/ 3 leaves for thrips among the different test hybrids without significant differences. The incidence of American bollworm is very low which was observed for a very short period only with less than 0.5 % square damage in all the hybrids and incidence of pink bollworm and tobacco caterpillar was nil during the crop growth period. The incidence of leaf hoppers was lowest in the hybrid, Western Nirogi 108 Bg II (2.3/ 3 leaves) and highest was recorded in SCH 777 (11.3/ 3 leaves). The hybrid, Surpass Asha recorded lowest incidence of whiteflies (0.93/ 3 leaves) and the highest incidence of whiteflies was recorded in the hybrid, Ankur 2595 (13.4/ 3 leaves).

Key words: *Bt* cotton hybrids, sucking pests, unprotected conditions

Cotton (*Gossypium hirsutum*) the 'White Gold', is one of the most important commercial crop playing a key role in Indian agriculture and economics which is cultivated under varied agro–climatic conditions across the major states of India. The crop is infested by about 1326 insect pests all over the world, however only 166 of them are reported to damage the crop in India (Hargreaves, 1948). However, *Bt* cotton incorporated with *Cry 1 Ac* and Cry 2ab are known to be resistant against major bollworms and several scientists have been already reported the efficacy of *Bt* cotton in India and abroad. However, they attract more sucking pests *viz.,* jassids, *Amrasca biguttula biguttula* (Ishida); thrips, *Thrips tabaci* (Linn.); aphid, *Aphis gossypii* (Glover) and whiteflies, *Bemisia tabaci* (Genn.) from seedling stage to boll development and harvesting stages. Sucking pests are known to cause heavy losses to the tune of 21.20 to 22.86 per cent (Kulkarani *et al.*, 2003 and Satpute *et al.*, 1990) in cotton besides acting as vectors for a number of viral diseases (Sreedhar *et al.*, 1999). The cultural practices such as use of resistant/tolerant varieties is a prime factor to minimise the damage due to insect pests and yield losses which can be used for devising the IPM strategies. Screening results in selection of some promising material with tolerance to sucking insect pests and other biotic stresses besides having good yields. The resistance/ tolerance entries could be taken up for advanced screening to assist in varietal improvement at later stages. In view of the above, the present study was taken up to evaluate the *Bt* cotton hybrids for the incidence of sucking pests under unprotected conditions.

MATERIALS AND METHODS

A field study was conducted to evaluate the *Bt* cotton hybrids against sucking pests at RARS, Lam during 2013-2015. A total of 62 hybrids were evaluated against sucking pests which were replicated twice in a randomised block design (RBD). The test hybrids were sown each in two rows of 8 meters length during the first week of August at a spacing of 105 x 60 cm. All the agronomic practices were followed as per the recommendations of ANGRAU to attain good crop growth. The hybrids were maintained completely under unprotected conditions throughout the crop growth period except against diseases to avoid crop loss due to diseases. The data regarding the Incidence of sucking pests *viz.,* leafhoppers, whiteflies, thrips and aphids per three leaves was recorded from 5 randomly selected plants from each hybrid at 30 and 60 days after sowing.

RESULTS AND DISCUSSION

Among the different sucking pests, leafhopper incidence was moderate to high, where as aphids, and whitefly incidence was low to medium and the thrips incidence was very low. The incidence of leaf hoppers was ranged from 2.3 to 11.3/ 3 leaves, while whiteflies were ranged from 0.9 to 13.4/3 leaves with significant differences among the different hybrids. Similarly the incidence of aphids ranged from 1.6 to 20.9/ 3 leaves among the entries with significant differences. But, there were no significant difference regarding the incidence of thrips among the test hybrids which was ranged from 0.1 to 2.4/ 3 leaves. The incidence of *Helicoverpa armigera* is very low with less than 0.5 per cent square damage in all the entries and incidence of pink bollworm and tobacco caterpillar was nil during the crop growth period. Among the different test hybrids, 30 and 34 hybrids recorded low incidence, whereas 12 and 14 hybrids recorded higher incidence of leaf hoppers and whiteflies, respectively. The incidence of leaf hoppers was lowest in the hybrid, Western Nirogi 108 Bg II (2.3/ 3 leaves) and highest was recorded in SCH 777 (11.3/ 3 leaves). The hybrid, Surpass Asha recorded lowest incidence of whiteflies (0.93/ 3 leaves) and the highest incidence of whiteflies was recorded in the hybrid, Ankur 2595 (13.4/ 3 leaves). The incidence of aphids was lowest in KCH 3041 (1.6/ 3 leaves) and highest was recorded in the DPC 5102 hybrid (20.9 / 3 leaves) (Table.1). However, multi location testing is essential to substantiate the tolerance/ resistance of hybrids.

Several screening studies were conducted by various scientists at different locations with different hybrids/varieties. Earlier, Gupta *et al.*, (1997) reported maximum numbers of thrips on cotton cultivars H 4, H 6, JKH 1, DCH 32 and AHH 468 during second fortnight of August. According to Patel *et al.*, (2010a), the highest jassid population was recorded in RCH II BG II (5.85) and found most susceptible. Vikram 5 *Bt* (2.12), G.Cot.hy.10 (2.32) and Akka N*Bt* (2.60) recorded significantly lower population than rest of the varieties. NCS 954 *Bt* of Mon 531 event was categorised as the most tolerant against both jassids and mealy bugs among 52 *Bt* hybrids (Patel *et al.*, 2010b).

Table 1. Incidence of sucking pests in different Bt cotton hybrids at RARS, Lam during 2013-2014 under unprotected conditions

S.No	Hybrid	Number/3 leaves			
		Leafhoppers	Aphids	Thrips	Whitefly
1	Western Nirogi 108 BG II	2.3 (1.82)	6.5 (2.74)	0.7 (1.3)	8.9 (3.15)
2	NCH 2108	3.1 (2.02)	9.7 (3.27)	1.6 (1.61)	7.3 (2.88)
3	AC H 4	5.0 (2.45)	9.1 (3.18)	0.3 (1.14)	5.9 (2.63)
4	SCH 505	4.1 (2.26)	4.9 (2.43)	1.2 (1.48)	7.5 (2.92)
5	KSCH 207	4.3 (2.30)	3.3 (2.07)	0.5 (1.22)	6.6 (2.76)
6	Bunny	8.6 (3.1)	8.6 (3.1)	0.6 (1.26)	2.8 (1.95)
7	ACH 2	3.7 (2.17)	6.0 (2.65)	1.9 (1.7)	8.5 (3.08)
8	KCH 3011	8.5 (3.08)	7.8 (2.97)	0.7 (1.3)	4.6 (2.37)
9	SWCH 4823	4.9 (2.43)	12.8 (3.71)	0.4 (1.18)	11.7 (3.56)
10	PCHH 4 (Saraswathi)	5.2 (2.49)	4.7 (2.39)	1.1 (1.45)	5.5 (2.55)
11	ACH 1	3.1 (2.02)	6.1 (2.66)	0.7 (1.3)	8.1 (3.02)
12	NBC 101	4.0 (2.24)	7.2 (2.86)	1.3 (1.52)	2.7 (1.92)
13	SCH 311	2.5 (1.87)	10.0 (3.32)	1.9 (1.7)	5.3 (2.51)
14	Mallika	5.9 (2.63)	12.5 (3.67)	0.9 (1.38)	1.7 (1.64)
15	Ankur 2595	3.4 (2.1)	6.9 (2.81)	0.8 (1.34)	13.4 (3.79)
16	Western Niogi 51	3.7 (2.17)	16.2 (4.15)	1.4 (1.55)	6.3 (2.7)
17	ACHH 2	7.6 (2.93)	10.4 (3.38)	1.1 (1.45)	2.3 (1.82)
18	JKCH 8905	6.0 (2.65)	9.6 (3.26)	0.3 (1.14)	3.9 (2.21)
19	KCH 3021	9.3 (3.21)	5.5 (2.55)	0.3 (1.14)	4.3 (2.3)
20	KSCH 232	4.9 (2.43)	6.4 (2.72)	1.1 (1.45)	4.5 (2.35)
21	DPC 5102 (Aravind)	4.2 (2.28)	20.9 (4.68)	1.3 (1.52)	5.0 (2.45)
22	First class	4.1 (2.26)	8.8 (3.13)	0.8 (1.34)	6.3 (2.7)
23	IAHH 4202	7.0 (2.83)	11.3 (3.51)	0.3 (1.14)	3.9 (2.21)
24	DPC 9104 (Aravind)	4.5 (2.35)	12.4 (3.66)	0.8 (1.34)	5.0 (2.45)
25	ACH 104 2	5.3 (2.51)	11.0 (3.46)	0.7 (1.3)	8.5 (3.08)
26	Mallika	5.1 (2.47)	4.7 (2.39)	1.3 (1.52)	1.9 (1.7)
27	KSCH 233	3.9 (2.21)	5.6 (2.57)	1.5 (1.58)	5.9 (2.63)
28	81 SS 33	5.9 (2.63)	1.9 (1.7)	2.2 (1.79)	4.7 (2.39)
29	PCHH 5073 (Meenakshi)	5.3 (2.51)	8.1 (3.02)	0.5 (1.22)	8.6 (3.1)
30	60 SS 66	8.2 (3.03)	6.4 (2.72)	0.3 (1.14)	3.6 (2.14)
31	Ankur 3818	6.6 (2.76)	3.6 (2.14)	0.6 (1.26)	12.6 (3.69)
32	Bunny	5.0 (2.45)	8.3 (3.05)	0.3 (1.14)	3.3 (2.07)
33	KCH 3041	4.2 (2.28)	1.6 (1.61)	0.5 (1.22)	2.4 (1.84)
34	KSCH 209	3.9 (2.21)	10.4 (3.38)	1.8 (1.67)	2.4 (1.84)
35	741 SS 66	6.8 (2.79)	5.5 (2.55)	0.6 (1.26)	8.4 (3.07)
36	Ankur 5464	9.0 (3.16)	2.3 (1.82)	0.1 (1.05)	1.6 (1.61)
37	SP 7585	5.3 (2.51)	11.9 (3.59)	0.4 (1.18)	4.8 (2.41)
38	Ankur 2224	6.4 (2.72)	8.1 (3.02)	1.2 (1.48)	2.4 (1.84)
39	KSCH 229	7.0 (2.83)	14.8 (3.97)	0.8 (1.34)	9.3 (3.21)
40	SCH 234	5.0 (2.45)	5.0 (2.45)	0.9 (1.38)	3.5 (2.12)
41	KCH 3031	5.4 (2.53)	4.5 (2.35)	0.4 (1.18)	4.3 (2.3)
42	RCH 797	5.1 (2.47)	12.7 (3.7)	2.4 (1.84)	3.0 (2)
43	IAHH 178	6.9 (2.81)	5.0 (2.45)	1.4 (1.55)	1.7 (1.64)
44	KCH 3001	7.4 (2.9)	9.4 (3.22)	0.7 (1.3)	6.5 (2.74)

45	Surpass Asha	9.3 (3.21)	3.7 (2.17)	0.4 (1.18)	0.93 (1.38)
46	NCH 1311	4.6 (2.37)	5.2 (2.49)	1.9 (1.7)	6.9 (2.81)
47	Ankur 4858	3.1 (2.02)	7.6 (2.93)	1.8 (1.67)	5.1 (2.47)
48	DPC 7102 (Arind)	5.8 (2.61)	6.0 (2.65)	0.9 (1.38)	3.4 (2.1)
49	63 88 33	5.5 (2.55)	9.1 (3.18)	1.0 (1.41)	6.6 (2.76)
50	NCH 1049	6.1 (2.66)	6.1 (2.66)	1.6 (1.61)	2.1 (1.76)
51	Mallika	8.2 (3.03)	1.8 (1.67)	1.9 (1.7)	1.2 (1.48)
52	RCH 779	4.3 (2.3)	5.5 (2.55)	1.2 (1.48)	10.0 (3.32)
53	NBC 102	5.9 (2.63)	6.7 (2.77)	0.7 (1.3)	6.9 (2.81)
54	Bunny	5.7 (2.59)	2.4 (1.84)	0.8 (1.34)	4.8 (2.41)
55	SP 7517	6.1 (2.66)	11.1 (3.48)	1.45 (1.57)	2.1 (1.76)
56	DPC 9105 (Arind)	4.2 (2.28)	1.7 (1.64)	1.5 (1.58)	5.0 (2.45)
57	KSCH 234	6.6 (2.76)	10.0 (3.32)	0.7 (1.3)	6.2 (2.68)
58	SCH 777	11.3 (3.51)	3.2 (2.05)	0.3 (1.14)	2.7 (1.92)
59	SCH 333	7.7 (2.95)	2.2 (1.79)	0.7 (1.3)	2.5 (1.87)
60	Jaadoo	4.6 (2.37)	11.2 (3.49)	1.2 (1.48)	8.8 (3.13)
	CD (p=0.05)	0.46	0.64	NS	0.94
	CV (%)	11.0	14.8	13.7	18.4

Figures in Parenthesis are Square root (X+1) transformed values

REFERENCES

Hargreaves, H. 1948. List of recorded cotton insects of the world, Common Wealth. Institute of Entomology, London,.: 50.

Gupta, M. P., Sharma, S. and Shrivastava, S. K. 1997. Population buildup of some sap–sucking insect on cotton in M.P. *Jour. Insect Sci.* **10** : 53–56.

Kulkarni, K.A., Patil, S. B. and Udikeri, S. S. 2003. Status of sustainable IPM of cotton pests: A scenario in Karnataka; In Proceedings of National Symposium on *"Sustainable Insect Pest Management"*, Feb 6–7, 2003, ERI, Loyala College, Chennai.:45

Satpute, U. S., Patil, V. N., Katole, S. R., Men, U. B., Bhagwat, V. R. and Thakare, A. Y. 1990. Avoidable losses due to sucking pests and bollworms in cotton. *Jour. App. Zoo. Res.,* **1:** 67–72.

Sreedhar, S., Ulrich, K. and Nedim, U. 1999. Development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on three malvaceae hosts. *Tribal Jour. Agri. Forest.* **23 :** 637–43.

Patel, S. M. and Bharpoda, T.M. 2010a. Screening of *Bt* cotton varieties for their susceptibility to leaf hopper and mechanism of Resistance. . In Proceedings of National conference on *"Paradigm shift in Cotton Research and Cultivation"*. October 19-21, 2011 pp. 24.

Patel. C.J., Bhadauriya, S., Desai H.R., Maisuria, I.M., Solanki, V.Y. and Kumar, V. 2010b. Reaction of *Bt* cotton hybrids to Jassids, *Amrasca bigitula bigitula* (Ishida) and mealy bug, *Phenococcus solenopsis* Tinsley. In Proceedings of National conference on *"Paradigm shift in Cotton Research and Cultivation"*. October 19-21, 2011. pp. 16-17.

Integrated management of foliar diseases in cotton

S. L. BHATTIPROLU*, N. V. V. S. DURGA PRASAD, K. V. SIVA REDDY AND V. CHENGA REDDY

Acharya N G Ranga Agricultural University, Regional Agricultural Research Station, Guntur – 522 034

E-mail: bhattiprolu2023@gmail.com

ABSTRACT: Three modules were evaluated to develop integrated management of foliar diseases in cotton. Module I was composed of Seed treatment with *Pseudomonas fluorescens* @ 10g/kg seed and soil application of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays with *P. fluorescens* (1%) at 60 and 90 days after sowing (DAS). Module II involved seed treatment with *P. fluorescens* @ 10g/kg seed followed by need based foliar sprays with propiconazole (0.1%) for Alternaria leaf spot at 60 DAS and copper oxychloride (COC) @ (0.3%) + Streptocycline (0.01%) for bacterial blight at 90 DAS (or) carbendazim (0.1%) at 60 DAS against grey mildew and propiconazole (0.1%) for Alternaria leaf spot and rust at 90 DAS. Module III included seed treatment with *P. fluorescens* @ 10g/kg seed and soil application of *Trichoderma viride* @ 2.5kg/ha followed by need based foliar sprays with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC (0.3%) + streptocycline (0.01%) for bacterial blight at 60 and 90 DAS. Pooled data showed that the modules were significantly superior against Alternaria leaf spot and bacterial blight in Jadoo BG II and RCH BG II. Modules I and II significantly reduced grey mildew in both the hybrids. Module II and III gave best control of rust in Jadoo BG II while module I and III were superior in RCH 2 BG II. All three modules resulted in significant increase in the yield of Jadoo BG II while modules I and II gave superior yields in RCH 2 BG II. Module III resulted in highest Incremental Benefit Cost Ratio (IBCR) of 1.35 in Jadoo BG II followed by module I while module II gave maximum IBCR of 1.30 in RCH 2 BG II.

Key words: Cotton, foliar diseases, integrated disease management

Cotton is an important fibre crop in India, cultivated in 126.55 lakh ha with 400 lakh bales (each bale of 170kg lint) production and a productivity of 537kg lint/ha during 2014-15 season. Andhra Pradesh stood 5th in area (7.36 lakh ha) and 6th in production (21.10 lakh bales) as well as productivity (624 kg/ha) during 2014 – 2015 (Anonymous, 2015). Cotton crop is affected by a number of foliar diseases throughout the season. Altenaria leaf spot, bacterial blight, grey mildew and rust diseases cause significant yield losses under congenial conditions (Monga *et al* 2013). Spraying copper fungicide (0.3%) mixed with streptocycline (0.01%) control foliar diseases. Propiconazole is effective against Alternaria leaf spot and rust diseases (Bhattiprolu and Prasad Rao, 2009, Monga *et al* 2013). Carbendazim is recommended to prevent losses due to grey mildew (Bhattiprolu, 2012). With these recommendations against individual diseases, an experiment was conducted to develop modules for integrated management of foliar diseases in cotton.

MATERIALS AND METHODS

A field trial was laid out at Regional Agricultural Research Station, Lam, Guntur during *kharif* 2011 to 2013. Eight treatments (three modules with two *Bt* hybrids plus controls) were replicated thrice in plots of 50 sq. m by adopting a spacing of 105 x 60 cm in randomized block design. Module I (T1 and T4) was composed of seed treatment (ST) with *Pseudomonas fluorescens* @ 10g/kg seed and soil application (SA) of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays with *P. fluorescens* (1%) at 60 and 90 days after sowing (DAS). Module II (T2 and T5) involved ST with *P. fluorescens* @ 10g/kg seed followed by need based foliar sprays with propiconazole (0.1%) for Alternaria leaf spot at 60 DAS and copperoxy chloride (COC) (0.3%) + Streptocycline (0.01%) for bacterial blight at 90 DAS (or) carbendazim (0.1%) at 60 DAS against grey mildew and propiconazole (0.1%) for Alternaria leaf spot and rust at 90DAS. Module III (T3 and T6) included ST with *P. fluorescens* @ 10g/kg seed and SA of *Trichoderma viride* @ 2.5kg/ha followed by need based foliar sprays with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC (0.3%) + streptocycline (0.01%) for bacterial blight at 60 and 90 DAS. Control plots (Jadoo BG II of T7 and RCH 2 BG II T8) received no protection for diseases. Data on bacterial blight, Alternaria leaf spot, grey mildew and rust were recorded using 0 to 4scale and per cent disease control in each treatment was calculated. Treatment wise yield data and increase in yield over control was recorded. Treatment wise net returns and incremental benefit cost ratio (IBCR) was calculated.

RESULTS AND DISCUSSION

Pooled data showed that all three modules were significantly superior against Alternaria leaf spot and bacterial blight in Jadoo BG II and RCH BG II (Table 1). Modules I and II significantly reduced grey mildew in Jadoo BG II. The disease intensity was low in RCH BG II. Module III recorded the lowest rust intensity (9.96%) in Jadoo BG II, while module II was on par. Module I and module III were superior against rust in RCH 2 BG II (Table 1).

Efficacy of biocontrol agent, *P. fluorescens* as seed treatment followed by foliar applications was found effective against Alternaria leaf spot, bacterial blight and grey mildew (Bhattiprolu, 2010; Chattanavar *et al.,* 2010). Efficacy of seed treatment with endospore forming bacteria against foliar, seed/soil borne diseases of cotton was reported by Medeiros *et al.,* (2015). Module I involving *P. fluorescens* confirms these findings. Efficacy of carbendazim against grey mildew as part of module II and III, in susceptible *Bt* hybrid like Jadoo is in agreement with Bhattiprolu (2012) and Monga *et al.,* (2013). Management of bacterial blight with combination of COC and streptocycline in modules II and III validates the previous works (Bhattiprolu, 2013; Monga *et al.,* 2013). Nunkumar (2006) reported the use of *T. harzianum* against *Phakopsora pachyrhiza* causing soybean rust. Efficacy of Module III using foliar applications with kresoxim methyl and combination of captan and hexaconazole also confirms reports of Bhattiprolu (2010), Chattanavar *et al.,* (2010) and Bhattiprolu (2015). All three modules resulted in significant increase in the yield in the range of 20.34 per cent to 34.75 per cent. Maximum IBCR of 1.35 was recorded with module III followed by module I (1.31) and module II (1.30). Module III resulted in highest IBCR of 1.35 in Jadoo BG II followed by module I while module II gave maximum IBCR of 1.30 in RCH 2 BG II (Table 1). In conclusion farmers are advised to adopt integrated management of foliar diseases using recommended biocontrol agents and/or chemicals.

Table 1. Integrated management of foliar diseases in cotton (Pooled data, 2011-13)

Treatment	Per cent Disease Intensity (PDI)				Reduction in disease (%)				Seed cotton yield (q/ha)	Increase in yield (%)	Incremental Benefit Cost Ratio
	Alternaria leaf spot	Bacterial blight	Grey mildew	Rust	Alternaria leaf spot	Bacterial blight	Grey mildew	Rust			
T1	10.34 (18.72) a	7.49 (15.79)a	12 (20.27)c	13.67 (21.68)b	62.7	54.5	69.23	52.68	13.45a	30.2	1.31
T2	11.24 (19.55) a	9.7 (18.15)a	11 (19.37)c	11 (19.37)a	59.45	41.07	71.79	61. 90	12.90a	24.88	1.25
T3	11.63 (19.91)a	8.7 (17.21)a	15 (22.79)d	9.96 (18.39)a	58.04	46.84	61.54	65.52	13.92a	34.75	1.35
T4	11.33 (19.64)a	7.66 (16.06)a	2 (8.13)a	10.19 (18.58)a	59.2	38.25	73.33	61.86	12.70a	25.37	1.26
T5	10.72 (19.09) a	9.49 (17.90)a	3 (9.89)a	14.17 (22.1)b	61.4	42.1	60	46.99	13.16a	29.91	1.3
T6	11.01 (19.37) a	7.5 (15.89)a	5.9 (14.06)b	11.59 (19.87)a	60.35	54.24	21.33	55.5	12.19b	20.34	1.21
T7	27.72 (31.76)b	16.46 (23.89) b	39 (38.65)e	28.89 (32.49)c					10.33c		
T8	27.77 (31.79)b	16.39 (23.85) b	7.5 (15.89)b	26.72 (31.11)c					10.13c		
CD (p=0.05)	1.26	2.269	3.373	2.824					0.8		
CV (%)	4.7	12.4	16.7	10.40					3.70		

*Figures in parentheses are transformed values. Figures marked with same letters are not significantly different.

T1 and T4 - Seed treatment (ST) with *Pseudomonas fluorescens* @ 10g/kg seed and soil application (SA) of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays (FS) with 1% *P. fluorescens* at 60 and 90 days after sowing (DAS); T2 and T5 - ST with *P. fluorescens* @ 10g/kg seed followed by need based FS with propiconazole 0.1% for Alternaria leaf spot at 60 DAS and copper oxy chloride (COC) @ 0.3% + Streptocycline @ 0.01% for bacterial blight at 90 DAS (or) carbendazim 0.1% at 60 DAS against grey mildew and propiconazole 0.1% for Alternaria leaf spot and rust at 90 DAS; T3 and T6 - ST with *P. fluorescens* @ 10g/kg seed and SA of *Trichoderma viride* @ 2.5kg/ha followed by need based FS with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC @ 0.3% + streptocycline @ 0.01% for bacterial blight at 60 and 90 DAS; T7 and T8 – No protection for diseases. Jadoo BG II (T1, T2, T3 and T7) and RCH 2 BG II (T4, T5, T6 and T8) were the test hybrids.

REFERENCES

Anonymous, 2015. AICCIP Annual Report (2014-15). All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Bhattiprolu, S. L. 2015. Efficacy of Kresoxim methyl against foliar diseases of Cotton. *J. Cotton Res. Dev.* **29** : 112-15.

Chattannavar, S. N., Hosagoudar, G. N. and Ashtaputre, S. A. 2010. Chemical and biological management of major foliar diseases of cotton. *Karnataka J. Agric. Sci.* **23** : 599-601.

Monga, D., Sree Lakshmi, B. and Prakash, A. H. 2013. Crop losses due to important cotton diseases. Central Institute for Cotton Research, Regional Station, Sirsa, India, *Tech. Bull.* No. **1** : 23.

Medeiros, F. H.V.D., Souza, R. M. D., Ferro, H. M,, Zanotto E, Machado, J. D.C., et al. 2015. Screening of Endospore-Forming Bacteria for Cotton Seed Treatment against Bacterial Blight and Damping-off. Adv. Plants Agric. Res. 2 (4): 00056. DOI: 10.15406/apar.2015.02.00056.

YOUNG SCIENTIST AWARD PAPERS

Molecular characterization of upland cotton (*Gossypium hirsutum* L.) by using RAPD markers

J. D. DESHMUKH AND D. B. DEOSARKAR
Department of Agricultural Botany,Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani - 431 402
E-mail : dbdeosarkar@gmail.com

Abstract : The present study attempts to evaluate 15 genotypes of G. *hirsutum* L. to study the genetic diversity by using Random Amplified Po lymorphic DNA (RAPD) analysis. Polymerase chain reaction (PCR) was carried out by using 25 random decamer primers. Twenty one primers were found polymorphic and produced 149 bands with 7.0 bands per primer. The polymorphism percentage ranged from 20 to 100 per cent. The genetic similarity coefficient for all genotypes ranged from 0.65 to 0.86 per cent. Cluster analysis separated in to three clusters which were corresponded well with their centers or sub centers or genetic relationship. The first major group comprised three cultivars (KH 120, KH 121 and L 765), cluster II comprised of three sub clusters (II A, II B and II C). Cluster II A comprised three cultivars (DHY 286 IR, MCU 5 and L 761). Cluster II B comprised 4 cultivars (NH 545, NH 572, PH 297 7 1 and PH 348). The cluster II C comprised three varieties (PH 44 1 2, PH 1009, PH 1024). The cluster III comprised single genotype *i.e.* Cocker showed 0.66 similarity index. The present study is also an endeavor in that direction and the information generated from it will useful to utilize in future cotton breeding programmes.

Key words : Cotton, PCR, RAPD

Cotton (*Gossypium hirsutum* L.) is currently the leading plant fibre crop worldwide and is grown commercially in the temperate and tropical regions of more than 50 countries. It is fibre, oil and protein yielding crops plays a crucial role in the economy of India. For multiple use of lint and byproducts cotton is also referred as "White Gold". A classical breeding has contributed tremendously in terms of quality and yield, further improvements in yield, fibre strength, length, water absorption and thermal properties are required for textile and other industrial applications. The potentials for improving these properties through classical breeding are limited. New technological advancement over the last decades in the field of genetics and plant breeding has provided the superior tools for detailed genetic analysis of agricultural crops. These considerations have led to the exploration of other techniques like DNA profiling. Molecular markers allow the breeder to dissect complex traits without exhaustive field screening over time and space, thus avoid the unreliable phenotypic assays. DNA markers are successfully applied in identification of genotypes with better fibre quality genes, which can fetch good price to Indian farmers (Waghmare *et al.*, 2005).

Among several molecular techniques, Randomly Amplified Polymorphic DNA *i.e.* RAPD is widely used due to technical simplicity and comparative high speed of technology. It is useful technique for construction of genetic linkage map because amplified DNA fragments originating from segregating population are inherited as dominant or recessive genes following the classical Mendelian pattern. RAPDs are dominant markers which discriminate the individuals on the basis of presence or absence of particular RAPD band (Livneh and Vardi, 1998). A present study was conducted in attempt to study genetic diversity within 15 cotton genotypes.

MATERIALS AND METHODS

The genomic DNA of 15 cotton genotypes *viz.,* KH 120, DHY 286 IR, PH 297 7 1, KH 121, NH 572, L 765, L 761, PH 348, PH 330, PH 44 1 2, PH 1009, PH 1024, NH 545, Cocker, MCU 5 were used to study their genetic diversity. The genotypes are grown in plastic tray pots in a polyhouse. DNA was isolated by CTAB (Cetyle Tetra Methyl Ammonium Bromide) method described by Zhang and Stewart, (2000). Polymerase chain reaction (PCR) was carried out by using 25 random decamer primers. The amplified product of RAPD from Agarose gel images were scored for presence (1), absence (0). Data analysis was performed using NTSYS PC (Numerical Taxonomy System, Version 2.02). The SIMQUAL programme was used to calculate the Jaccard's coefficient. Dendrogram was constructed using unweighted pair group method for arithmetic mean (UPGMA) based on Jaccard's coefficient. The polymorphic percentage of the obtained bands were calculated by using formula, Polymorphic % = (Number of polymorphic bands/ Total bands) x 100.

RESULTS AND DISCUSSION

The genomic DNA from 15 cotton genotypes were evaluated to study the genetic diversity by using Random Amplified Polymorphic DNA (RAPD) analysis. Polymerase chain reaction (PCR) was carried out by using 25 random decamer primers. Perusal of data revealed that total 149 bands were observed with 7.0 bands per primer. RAPD analysis which revealed that twenty one primers were found polymorphic and four primers *viz.,* OPK 2, OPK 06, OPA 14 and OPA 19 were failed to amplify.

Banding pattern generated by primers

i) OPK 01, OPK 07, OPA 05 and OPA 20 : Total six bands each were produced by these primers, out of which five were polymorphic and one was monomorphic. Molecular polymorphism produced by these primers was 83.00 per cent.

ii) OPK 03 : Five bands were generated by OPK 03, four bands were polymorphic and one was monomorphic in nature. Level of polymorphism was 80.00 per cent.

iii) OPK 04 : Amplification product of OPK 04 accounts for five bands. One band was polymorphic and four were monomorphic. Thus level of polymorphism was 20.00 per cent.

iv) OPK 05 : OPK 05 primer generated eight bands out of which seven bands were found polymorphic. Thus OPK 05 primer showed 87.50 per cent polymorphism.

vi) OPK 08, OPK 09 and OPA 10 : The primers OPK 08, OPK 09 and OPa 10 generated seven bands each; out of seven bands six bands were polymorphic in nature. Polymorphism percentage was 85.71 per cent shown by these primers.

vii) OPA 06 : Ten bands generated by OPK 06, nine were polymorphic while one band was monomorphic in nature. Thus primer estimated 90.00 per cent polymorphism.

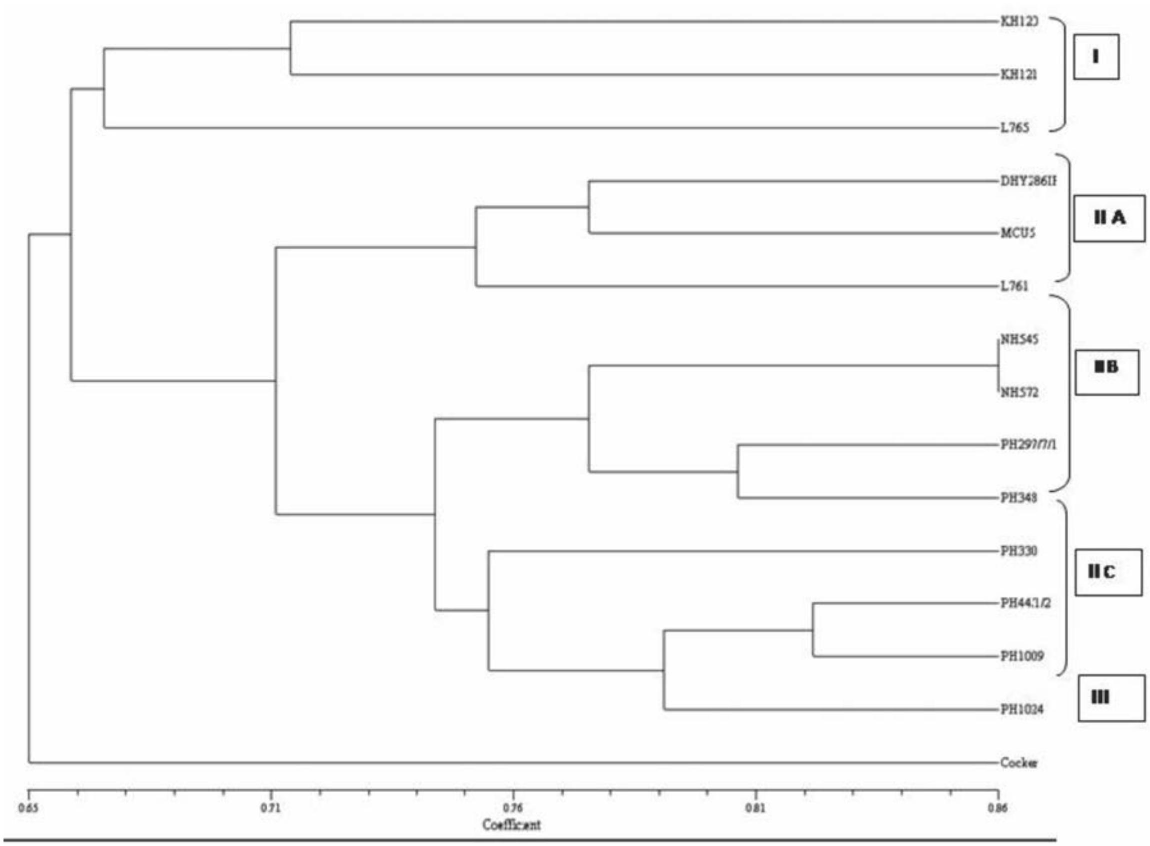

Fig. 1. Dendrogram showing the genetic similarity among 15 cotton genotypes as derived from RAPD data using the UPGMA

vii) OPA 07, OPA 08, OPA 11 and OPA 16 : The primers OPA 07, OPA 08, OPA 11 and OPA 16 had generated nine bands each, all these bands were polymorphic. No any unique or monomorphic band was observed. Molecular polymorphism percentage was accounted to 100 per cent.

viii) OPA 09 and OPA 17 : Total six bands each were generated by OPA 09 and OPA 17 three were polymorphic and three were monomorphic, thus produced 50 per cent polymorphism.

ix) OPA 12 : Total seven bands were produced by OPA 12, out of which four were polymorphic, three were monomorphic. Molecular polymorphism produced was 57.14 per cent.

x) OPA 13 : Total eight bands were produced by OPA 13, out of which three were polymorphic, five were monomorphic. The percentage of polymorphism was 37.50 per cent estimated by the primer OPA 13.

xi) OPA 15 and OPA 18 : Nine bands each were generated by the primer OPA 15 and OPA 18, six were polymorphic in nature. However three monomorphic band was observed. The percentage was 66.67 per cent projected by these primers.

It is evident from Table 2 that twenty one

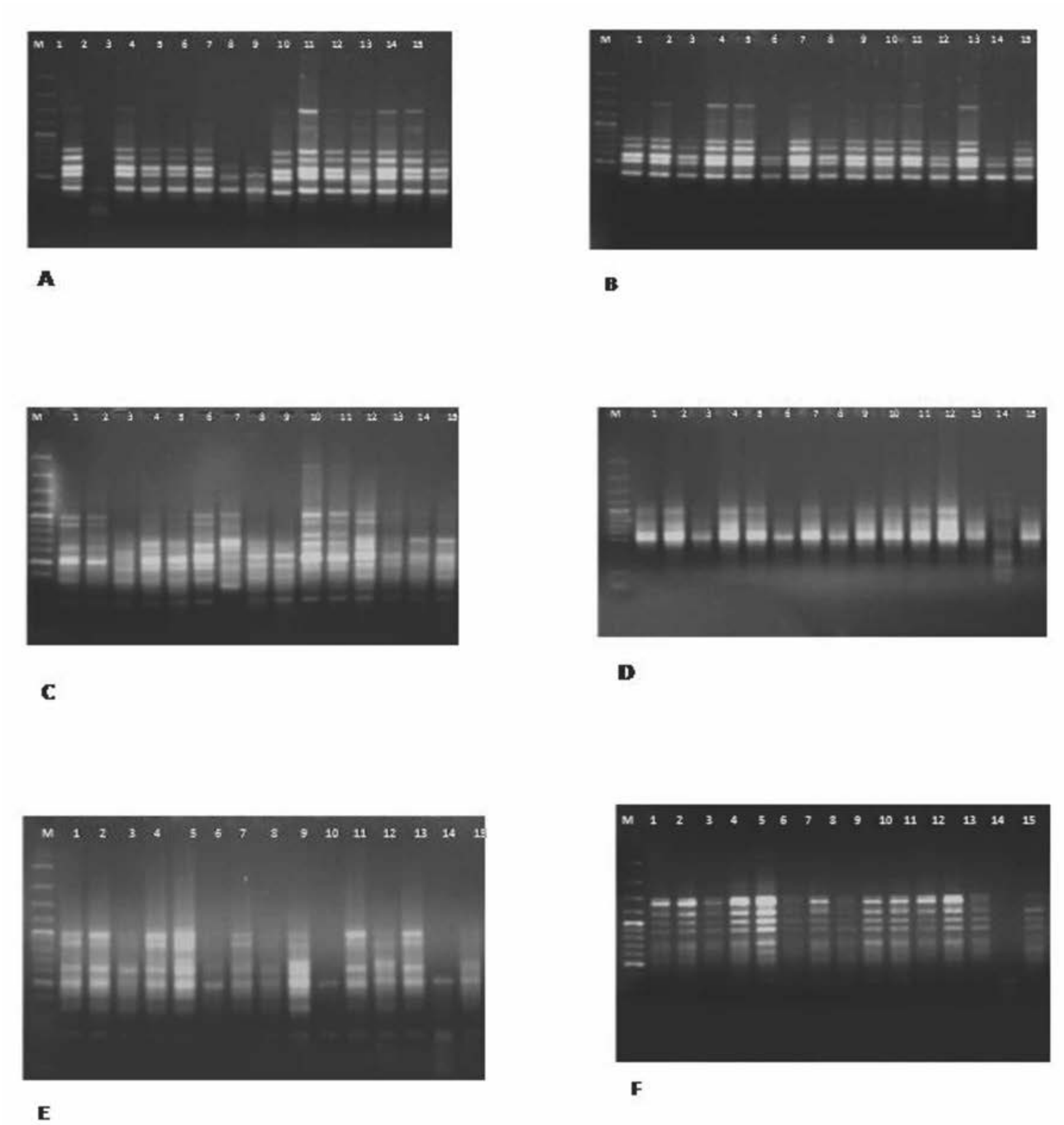

Plate 1. Amplified profile of 15 cotton genotypes with primers (A) OPA 08, (B) OPA 09 and (C) OPA 18. M = ladder, 1= KH 120, 2 = DHY 286 IR, 3 = PH 297 7 1, 4 = KH 121, 5 = NH 572, 6 = L 765, 7 = L 761, 8 = PH 348, 9 = PH 330, 10= PH 44 1 2, 11 = PH 1009, 12 = PH 1024, 13 = NH 545, 14 = Cocker, 15 =MCU 5.

polymorphic primers had generated 149 bands. Out of these bands 115 were found polymorphic and 34 were monomorphic. Appreciable amount of polymorphism (*i.e.* 20.00 to 100 %) had generated by these primers confirmed the genetic diversity present among the individual sample. Highly polymorphic primers like OPA 07, OPA 08, OPA 11 and OPA 16 had proved their significance for genetic diversity analysis in cotton.

Using RAPD polymorphism a dendrogram (Fig. 1) was constructed using unweighted pair group method of arithmetic means (UPGMA).

The vertical dashed lines in the

Table 1. Banding pattern generated by polymorphic primers in RAPD analysis of cotton genotypes

Sr. No.	Randomprimer	Total bands	Polymorphic bands	Monomorp hicbands	Polymorphism (%)
1	OPK-01	6	5	1	83.33
2	OPK-03	5	4	1	80.00
3	OPK-04	5	1	4	20.00
4	OPK-05	8	7	1	87.50
5	OPK-07	6	5	1	83.33
6	OPK-08	7	6	1	85.71
7	OPK-09	7	6	1	85.71
8	OPA-05	6	5	1	83.33
9	OPA-06	10	9	1	90.00
10	OPA-07	9	9	0	100.00
11	OPA-08	7	7	0	100.00
12	OPA-09	6	3	3	50.00
13	OPA-10	7	6	1	85.71
14	OPA-11	5	5	0	100.00
15	OPA-12	7	4	3	57.14
16	OPA-13	8	3	5	37.50
17	OPA-15	9	6	3	66.67
18	OPA-16	10	10	0	100.00
19	OPA-17	6	3	3	50.00
20	OPA-18	9	6	3	66.67
21	OPA-20	6	5	1	83.33

dendrogram assigned the genotypes into clusters which correspond well with their centers or sub centers or genetic relationship. In cluster I comprised three cultivars *viz.,* KH 120, KH 121 and L 765 with similarity 0.67, cluster II comprised of three sub clusters, cluster II A comprised three cultivars i.e. DHY 286 IR, MCU 5 and L 761 with similarity coefficient was ranging from 0.75 to 0.77. Cluster II B comprised four cultivars *viz.,* NH 545, NH 572, PH 297 7 1 and PH 348, indicating that they are more closely related which accounted similarity ranges from 0.77 to 0.80. The cluster II C comprised three varieties *viz.,* PH 44 1 2, PH 1009, PH 1024 with similarity value was ranged from 0.79 to 0.82. The cluster III comprised single genotype i.e. Cocker showed 0.66 similarity index. The findings are in accordance with Raina *et al.,* (2001), Archak and Gaikwad (2003), Dongre *et al.,* (2003), Zhang *et al.,* (2004), Dongre *et al.,* (2006), Ebtissam *et al.,* (2007), Zhang *et al.,* (2007), Patil *et al.,* (2007), Sharma *et al.,* (2007), Esmail *et al.,* (2008), Muhammad *et al.,* (2009) and Weian *et al.,* (2009).

REFERENCES

Archak, S., A.B. Gaikwad and O. Gautam. 2003. Comparative assessments of DNA fingerprinting techniques (RAPD, ISSR and AFLP) for genetic analysis of cashew (*Anacardium occidentale L.*) accessions of India. *Genome.* **46 :** 362-69.

Dongre, A.B. and V.J. Parkhi. 2003. Characterization of cotton (*Gossypium hirsutum*) germplasm by ISSR, RAPD markers and agronomic values. *The Indian J. Biotech.* **3 :** 388-93.

Dongre, A.B., M.R. Bhandarkar and V. J. Parkhi. 2006. Genetic analysis of wild species in support of evolutionary change of the genus *Gossypium* through ISSR markers. Indian J. Genet. **66 :** 279-82.

Ebtissam, H.A., Hussein, Marwa., H.A. Osman, H. Hussein and S. Adawy. 2007. Molecular characterization of cotton genotypes using PCR based markers, *J. Applied Sci. Res.* **3 :** 1156-69.

Esmail, R.M., J.F. Zhang and A.M. Abdul Hamid. 2008. Genetic diversity in elite germplasm lines using field performance and RAPD markers. *World J. Agric. Sci.* **4 :** 369-75.

Muhammad, A.M.U., M. Rahman, I. Javed and Y. Zafarwy. 2009. Parentage confirmation of cotton using molecular marker. *Pakistan J. Bot.* **41 :** 695-701.

Livneh, O. and E. Vardi 1998. "Hybrid Cultivar Development", S.S. Bauga and S.K. Banga (Eds.) Narosa Publishing House, New Delhi, India. 212-14.

Patil, M.D., D.P. Biraday, B.S. Patil and H.L. Nadaf. 2007. Analysis of genetic diversity of cotton genotypes using RAPD PCR technique. *Karnataka J. Agric. Sci.* **20 :** 215-17.

Raina, S.N., V. Rani, T. Kojima, Y. Ogibara, K.P. Singh and R.M. Devarumath. 2001. RAPD and ISSR fingerprint are useful genetic markers for analysis of genetic diversity, varietal identification and phytogenetic relationship in peanut (*Arachis hypogaea*) cultivars and wild species. *Genome.* **44 :** 763-72.

Sharma V., A. Jain, R.K. Behl, B.S. Chhabra, P.P. Jain and B.P.S. Lather. 2007. RAPD characterization of parental lines of some American cotton hybrids. *J. Cotton Res. Dev.* **21 :** 158-61.

Waghmare V.N., A.B. Dongre, V.R. Gajbhiye and S.V. Salem. 2005. Molecular mapping for fibre quality traits in cotton. National symposium on *"Improvement of fibre quality traits in cotton".* 96-103.

Weian. 2009. Genetic diversity in annual wild soybean (*Glycine soja.*) and cultivated soybean (*G. Max.*) from different latitudes in China. *Pakistan J. Bot.* **41 :** 2229-42.

Zhang, J.F. and J.M. Stewart, 2000. Economical and rapid method for extracting cotton genomic DNA. *J. Cotton Sci.* **4 :** 193-201.

Zhang, T.Z., Y.L. Yuan, W. Gao and R.J. Kohel. 2004. SSR molecular tagging of QTLs for fibre strength in upland cotton. *J. Agric. Sci.* **34 :** 363-366.

Zhang, X.V. and X.D. Wang. 2007. Relationship between molecular marker heterozygosity and hybrid performance in intra and interspecific hybrids of cotton. *J. Plant Breed.* **126 :** 385-91.

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Utilizing heterotic groups of cotton and forming sub groups for further exploitation based on combining ability pattern

H. G. KENCHARADDI, S. S. PATIL, R. R. HANCHINAL, K. J.,PRANESH AND S. M., MANJULA

Department of Genetic and Plant Breeding, University of Agricultural Sciences, Dharwad - 580 005

Email:hgkencharaddi@gmail.com

ABSTRACT : Recurrent selection for combing ability was practiced by utilizing heterotic box involving diverse heterotic groups (Robust /stay green *V/s* high RGR) of cotton. A set of two *intra hirsutum* single cross hybrids generated from two elite lines *viz.,* DRGR 24-178 and DRGR-32-100 of high relative growth rate (RGR) group and single elite line from robust line, DSMR-10 and stay green line DSG3-5. These two crosses were advanced to F_4 generation to assess the recombinational variability for combining ability existing among the F_4 lines derived from these crosses. An assessment of combining ability pattern and possibility of development of sub-populations against chosen tester (s) was made. In this method each F_4 line derived from elite lines of each heterotic group was characterized with respect to its combining ability status (pattern) considering the four opposite testers of opposite diverse group. With the help of this information, nature and magnitude of variability for combining ability was assessed individually and based on the derived F_1 performance four sub groups of F_4 lines were formed (A1,A2,A3 and A4….). Results indicated that with respect to reciprocal testers of both populations to enhance the productivity of the hybrids, it was recommended that A1/B1 sub population of high RGR F_4 lines and E1/F1 sub population of robust/stay green F_4 lines could be developed by recombining the best lines of DRGR-24-178 x DRGR-32-100 and DSMR-10 x DSG3-5. At the same time these superior lines could be used to inter cross between these sources as the distance between them was increased which could give a still better cross. By considering the common and diverse testers CT_3 (DH-7225) and DT_4 (DR-8) against high RGR F_4 lines of DRGR-24-178 x DRGR-32-100 and CT_7 (DH-7225) and DT_8 (DRGR-4) against robust/stay green F_4 lines of DSMR-10 x DSG3-5 cross, it was evident that entire group of lines revealed large variability for combining ability to combine with these testers. Between the group of lines tested, the F_4 lines of DRGR-24-178 x DRGR-32-100 was found to be combine much better with these common and diverse testers as compared to the F_4 lines of DSMR-10 x DSG3-5, which was evidenced by the higher frequency of lines falling under the superior category E1, F1, G1 and H1, respectively.

Key words : Combining ability, compact, groups, heterotic, high RGR, robust, stay green, sub grouping

Cotton is an immensely important agricultural crop for the sustainable economy and livelihood of the Indian farming community. It is cultivated in about 33.14 m. ha across the world and in about 11.70 m. ha in the county. India accounts for about 32 per cent of the global cotton area and contributes to 21 per cent of the global cotton produce (37.50 million bales), currently ranking second after China. The domestic consumption of cotton in India is about 25 million bales during 2013-2014. The productivity of cotton in India is about 540 kg/ha, whereas Australia holds highest productivity level (2151 kg/ha) among the major cotton growing nations.

The basic formula on heterosis ($HF_1 = Sdy^2$) explains how performance (heterosis) of hybrid depends on genetic diversity and extent of dominance existing at different yield influencing loci. It means heterosis can be enhanced either by increasing genetic distance or dominance. It is not possible to manipulate and enhance the degree of dominance and at best we may choose such populations which are differing for the allelic status of such yield influencing loci. If such two base populations are identified which are diverse from each other, it means the plants belonging to the two populations in general differ for the allelic status of yield influencing loci. If each of such chosen populations has inherent variability, this variability can be exploited through selection practised reciprocally to increase the genetic distance further between the populations. In essence, it amounts for widening the genetic distance between the populations (Falconer, 1981).

These principles of population improvement schemes are same in case of both cross and self pollinated crops but the procedure used for enhancing genetic distance (improving combining ability) will change depending upon the type of mating system of crop. Though commercial exploitation of heterosis has taken place at such a revolutionary scale, the hybrid breeding programs are not supported by development of hybrid oriented populations as seen in case of cross pollinated crops. In cross pollinated crops population improvement schemes involving improvement of combining ability as an integral step in evolving hybrids. There is urgent need for implementing such schemes of improving combining ability even in self pollinated crops by crossing the limits of mating system barriers.

In cotton, attempts were made to exploit genetic diversity by forming heterotic groups. Heterotic group is a group of related or unrelated genotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups. By comparison, the term heterotic pattern refers to a specific pair of two heterotic groups, which express high heterosis and consequently high hybrid performance in their cross. Following this line of expectation, an attempt was made at Dharwad to understand in general the complementation pattern of parents contributing to heterosis. The pattern of complementation for plant features has given rise to formation of different heterotic groups like stay green, robust, compact and high Relative Growth Rate (RGR) and their heterotic patterns like stay green x compact, robust x compact, robust x high RGR and stay green x high RGR which in general give potential hybrids.

Development of sub populations with improved combining ability is used as an important step of population improvement schemes in cross pollinated crop like maize. Grouping the lines based on the cross performance of a large set of lines with chosen tester, which could be a known best general combining line and also based on the combining ability status, the genotypes are assigned to the different groups like good, average and poor combiners.

MATERIALS AND METHODS

In the present research, an attempt was made to assess these opposite sets of recombinant lines derived from elite lines of each heterotic groups. The procedure of reciprocal recurrent selection is a method of population improvement practiced by involving diverse base populations (Comstock *et al.,* 1949). After identifying the heterotic box (DRGR-24-178 x DRGR-32-100) x (DSMR-10 x DSG 3-5) during

2009-10. The within group crosses *viz.,* DRGR 24-178 x DRGR 32-100 and DSMR 10 x DSG 3-5 were utilized for developing two diverse base populations for initiating reciprocal selection for combining ability. In both the populations, in the second year, three hundred seeds from each single cross F_1 were advanced to F_2 generation (*kharif*, 2010). In F_2 generation, two hundred good looking plants were selected from each single cross (plant to row progeny) during *kharif*, 2011 and advanced to F_3 generation (Summer, 2012). In F_3 generation, 50 lines were selected randomly and advanced to F_4 generation at Agriculture Research Station, Nipani and Main Agricultural Research Station, Dharwad. The selected 50 F_4 lines of high RGR heterotic group and stay green robust group were utilized for initiating reciprocal selection for combining ability.

The set of 50 high RGR-F_4 lines of DRGR-24-178 x DRGR 32-100 cross and Simultaneously, 50 RSG-F_4 lines of DSMR 10 x DSG-3-5 cross were selected for assessing the variability for combining ability. The set of 50 lines of DRGR 24-178 x DRGR 32-100 were crossed with two reciprocal testers *viz.,* DSMR-10 (RT_1) and DSG 3-5 (RT_2) and similarly 50 lines derived from DSMR 10 x DSG-3-5 were crossed to reciprocal testers *viz.,* DRGR 24-178 (RT_5) and DRGR 32-100 (RT_6). In addition, a new high combiner line (DH 2772) was developed during recent years which combined well with different groups and hence this was used as a common tester against both RGR and RSG-population. For assessing recombination variability for combining ability released in high RGR-F_4 lines, it was proposed to cross them with additional diverse robust lines recently added to the robust group and thus DR 8 (DT_4) was selected as an additional tester against high RGR lines. Similarly, a new high RGR line DRGR 4 (DT_8) was used to assess combining ability of robust/stay green F_4 lines. The efficiency of tester can be judged based on the overall mean of F_1 obtained with that tester and the variability observed among the tester crosses. The F_4 lines derived from DRGR 24-178 x DRGR 32-100 were referred to as population I and those from DSMR 10 x DSG3 5 were referred to as population II. Two hundred hybrids derived from these populations involving F_4 lines with testers were called as derived F_1's (dF_1s). (Fig. 1)

The material pertaining to population I (high RGR heterotic group F_4 lines, testers and its derived F_1s, bench mark crosses (original non parental crosses) and commercial *Bt* checks (Kanaka, Chiranjeevi and JK Durga) were raised in one block (Table 1) and that pertaining to population II (against stay green/robust F_4 lines) were raised in the adjoining block, during *Kharif*, 2013 at ARS, Belvatigi. (Table 2). The derived F_1s were planted in a randomized block design with two replications/each population. A spacing of 90 cm between rows and 60 cm between the plants within a row was followed, taking two rows/ replication and a row length of 4.80 m. Fertilizers at recommended doses were applied and other cultural practices were carried out at regular intervals. The plant protection measures were taken up at appropriate time to control pests and diseases.

Grouping of lines based on combining ability : The overall mean of all the crosses with the tester can be worked out and four sub groups of tester cross performance of combining ability can be made as stated below. This sub grouping of can be done separately for each of the testers with which they are crossed.

Based on the mean (of all the crosses), the crosses were divided into four classes and given the ranks as '1' (> mean + SD), '2' (mean to mean + SD), '3' (mean to mean – SD) and '4' (<

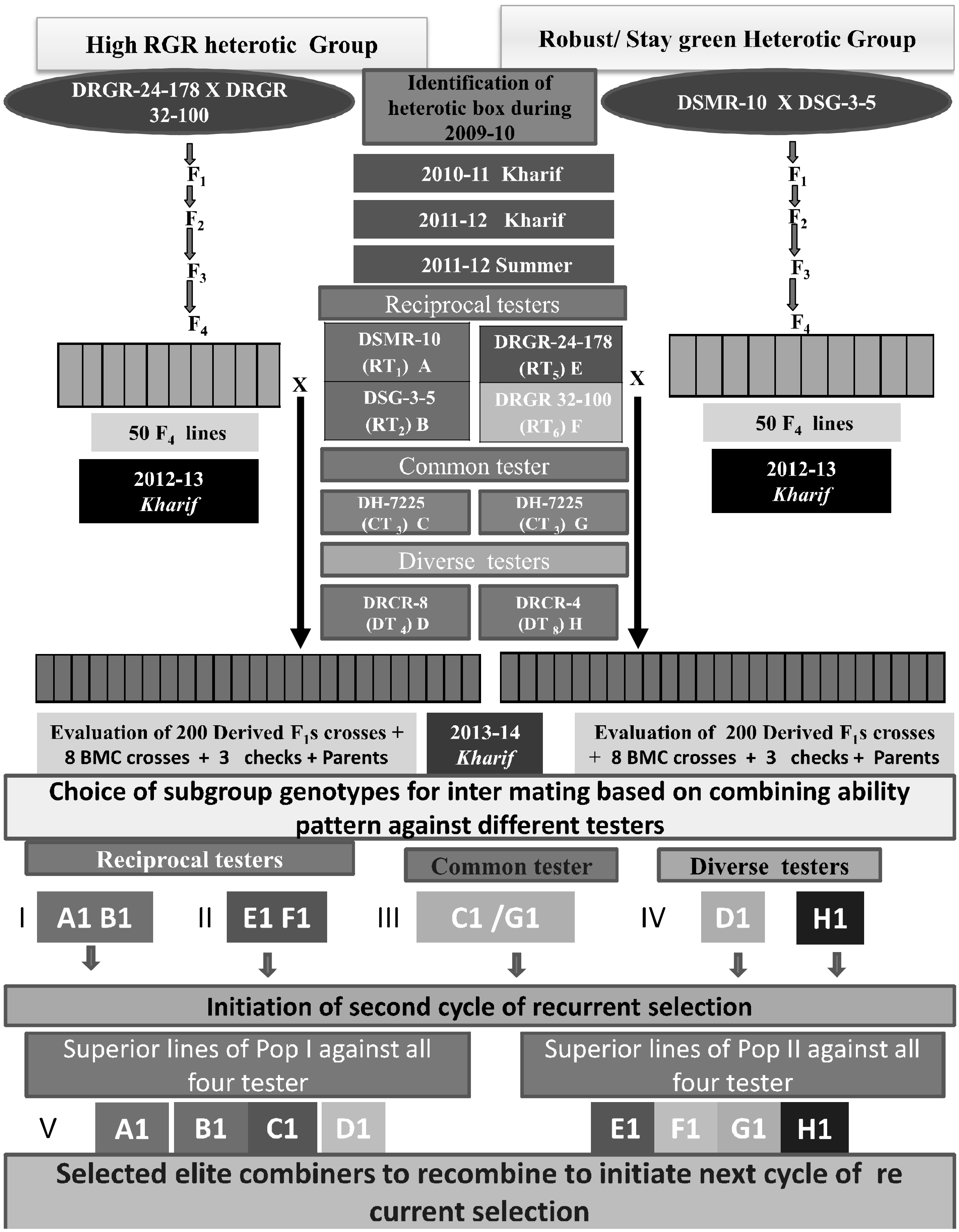


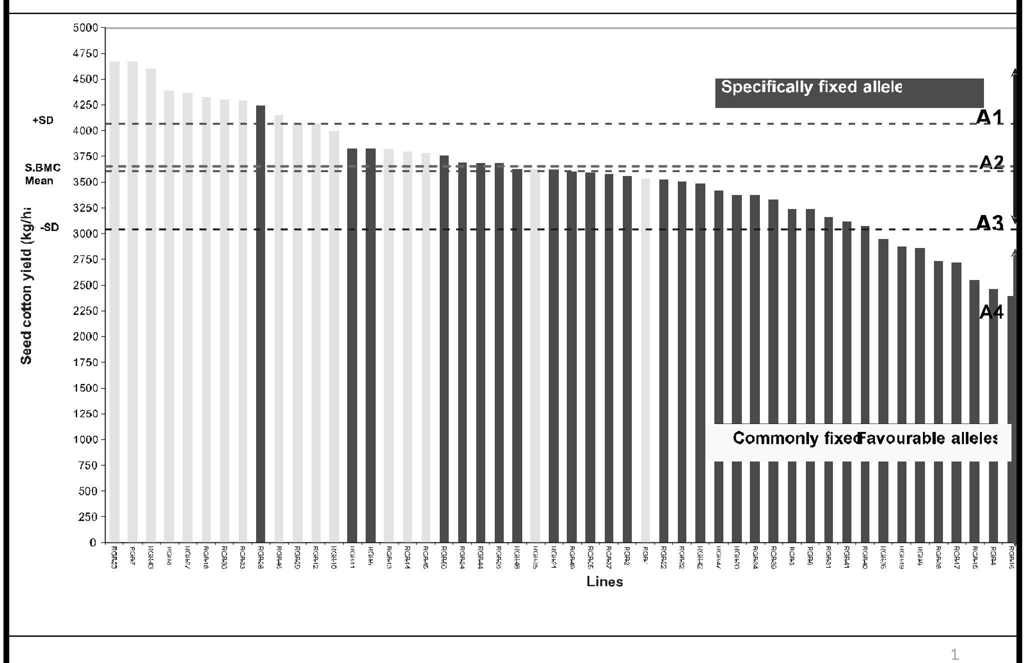
Fig. 1. Practicing one cycle of reciprocal selection for combining ability in cotton and forming sub groups based on combing ability pattern

mean – SD) as suggested by Patil (1995). Each line was characterized with respect to its combining ability status (pattern) against the testers. With the help of this information, the nature and magnitude of variability for combining ability was assessed.

The information obtained from the cross between the F_4 lines of both the population with respect to its combining ability status (pattern) to corresponding testers. By following the method of determining the combining ability pattern given above, each line of two populations were categorized and compared with the other lines. The A1 subgroup consist of the best combiner against the tester utilized. It means that these have possibly maximum number of favourable alleles and these favourable alleles compliment perfectly with the favourable alleles of the tester. From A1 sub group can be involved in developing the A1 sub population (Al-SP) for improving combining ability in general and combining ability with this tester in particular. This also means that the sub population can give which are most likely to combine very well with other from the population to which the tester represents.

In another form of graphical representation shown in Figures. Two testers can be chosen for representation, one on each axis. Here it has been shown by utilizing the derived F_1 performance of from pop I and II with the reciprocal , common and diverse testers inducted in the study. This form of representation helps in identifying the falling genotypes in 16 sub groups formed in each graph. The falling genotypes in AlBl similarly C1Dl, E1F1 and G1F1 subgroups represent the most potential combiners against the tester combinations concerned. In the same graph the mean performance of each sub group against the testers is depicted. Further, the scoring patterns of the are given and the top five crosses are

Fig 2.Combining ability status of F_4 lines of population I based on cross performance with Rol tester DSMR-10



marked from examining the combining ability pattern of the lines involved in the best crosses.

It is possible to choose revealing high combining ability against a particular chosen tester. Such chosen can be involved in developing sub population for improving combining ability against the chosen tester (s). For example, if the objective is to improve combining ability against RT_1, the representing A1 sub group can be utilized in developing A1 sub population which will recombine and accumulate favourable alleles for giving superior performance against RT_1.

RESULTS AND DISCUSSION

In this study, two complimentary populations (Pop I and II) which are developed from two diverse single cross F_1s, are crossed with each other by using opposite parents as a tester to identify those of pop I capable of combine well with pop II and *vice versa*. Among the F_4 lines of DRGR 24 187 x DRGR 32 100 (pop I), ten lines belongs to this group *viz*., RGR 23, RGR 7, RGR 43, RGR 8, RGR 27, RGR 18, RGR 30, RGR 33 RGR 28 and RGR 46 belonged to higher combiner category (A1) against the opposite tester DSMR 10 (RT_1) /A (Fig. 2). The ten F_4 lines *viz*., RGR 9, RGR 50, RGR 8, RGR 10, RGR 15, RGR 49, RGR 13, RGR 17, RGR 1 and RGR 12 fell under higher combiner category (B1) against the opposite population DSG3 5 (RT_2) /B (Fig. 3). In case of population II, F_4 lines of DSMR 10 x DSG3 5 *viz*., Seven F_4 lines RSG 31, RSG 17, RSG 45, RSG 19, RSG 25, RSG 36 RSG 23 and RSG 29 belonged to higher combiner category (E1) against the opposite tester DRGR 24 178 (RT_5) /E (Fig. 4). Whereas, 12 F_4 lines *viz.,* RSG 23, RSG 48, RSG 18, RSG 38, RSG 29, RSG 25, RSG 24, RSG 49, RSG 36, RSG 27, RSG 17 and RGR 50 fell under higher combiner category (F1) against the

Table 1. Parental genotypes used for study on exploitation of identified heterotic box through reciprocal selection combining ability involving high RGR F_4 lines of DRGR 24 178 x DRGR 32 100.

	50 F_4 lines of Population I (DRGR 24 178 x DRGR 32 100)		
Sl. No.	High RGR F_4 lines	Sl. No.	High RGR F_4 lines
1	RGR 1	26	RGR 26
2	RGR 2	27	RGR 27
3	RGR 3	28	RGR 28
4	RGR 4	29	RGR 29
5	RGR 5	30	RGR 30
6	RGR 6	31	RGR 31
7	RGR 7	32	RGR 32
8	RGR 8	33	RGR 33
9	RGR 9	34	RGR 34
10	RGR 10	35	RGR 35
11	RGR 11	36	RGR 36
12	RGR 12	37	RGR 37
13	RGR 13	38	RGR 38
14	RGR 14	39	RGR 39
15	RGR 15	40	RGR 40
16	RGR 16	41	RGR 41
17	RGR 17	42	RGR 42
18	RGR 18	43	RGR 43
19	RGR 19	44	RGR 44
20	RGR 20	45	RGR 45
21	RGR 21	46	RGR 46
22	RGR 22	47	RGR 47
23	RGR 23	48	RGR 48
24	RGR 24	49	RGR 49
25	RGR 25	50	RGR 50
Testers			
1	DSMR 10 (Reciprocal Tester) (RT_1)		
2	DSG 3 5 (Reciprocal Tester) (RT_2)		
3	DH 7225 (Common Tester) (CT_3) DR 8		
4	(Diverse Tester) (DT_4)		
Checks (Popular Bt hybrids)			
1	Kanaka *Bt*		
2	Chiranjeevi *Bt*		
3	JK Durga *Bt*		
Bench mark crosses			
1	DRGR 24 178 x DSMR10		
2	DRGR 32 100 x DSMR10		
3	DRGR 24 178 x DSG3 5		
4	DRGR 32 100 x DSG3 5		
5	DRGR 24 178 x DH 7225		
6	DRGR 32 100 x DH 7225		
7	DRGR 24 178 x DR 8		
8	DRGR 32 100 x DR 8		

Table 2. Parental genotypes used for the study on exploitation of identified heterotic box through reciprocal selection for combining ability involving robust/stay green (RSG) F_4 lines of DSMR 10 x DSG3 5

50 F_4 lines of Population II (DSMR 10 x DSG3 5)			
Sl. No.	Robust stay green lines	Sl. No.	Robust stay green lines
1	RSG 1	26	RSG 26
2	RSG 2	27	RSG 27
3	RSG 3	28	RSG 28
4	RSG 4	29	RSG 29
5	RSG 5	30	RSG 30
6	RSG 6	31	RSG 31
7	RSG 7	32	RSG 32
8	RSG 8	33	RSG 33
9	RSG 9	34	RSG 34
10	RSG 10	35	RSG 35
11	RSG 11	36	RSG 36
12	RSG 12	37	RSG 37
13	RSG 13	38	RSG 38
14	RSG 14	39	RSG 39
15	RSG 15	40	RSG 40
16	RSG 16	41	RSG 41
17	RSG 17	42	RSG 42
18	RSG 18	43	RSG 43
19	RSG 19	44	RSG 44

Testers

1 DRGR 24 178 (Reciprocal tester) (RT_5)
2 DRGR 32 100 (Reciprocal tester) (RT_6)
3 DH 7225 (Common tester) (CT_7)
4 DRGR 4 (Diverse tester) (DT_8)

Checks (Popular Bt hybrids)

1 Kanaka *Bt*
2 Chiranjeevi *Bt*
3 JK Durga *Bt*

Bench mark crosses

1 DRGR 24 178 x DSMR10
2 DRGR 32 100 x DSMR10
3 DRGR 24 178 x DSG3 5
4 DRGR 32 100 x DSG3 5
5 DSMR10 x DH 7225
6 DSG3 5 x DH 7225
7 DSMR10 x DRGR 4
8 DSG3 5 x DRGR 4

opposite population DRGR 32 100 (RT_6) /F (Fig 5). The superior F_4 lines of the two populations identified in this study are genetically more diverse than the original base populations. In the next phase of work, these superior lines from two populations need to be crossed between them to assess the performance of the crosses based on the lines improved through reciprocal selection for combining ability.

The number of lines selected for synthesizing a subpopulation may vary depending on the differences existing among the top order combiners. If just top two are distinctly superior than the rest and hence among the good combiner if top two are chosen they can be crossed to develop F_2 population. The segregating generations of this cross can be evaluated for combining ability by using the same tester. A pedigree method of breeding for combining ability can be followed in which selection is practiced for combining ability, the trait which is measured based on tester cross performance with the concerned tester.

Based on graphical presentation given for common tester, it was evident that lines of two populations revealed a larger variability for ability to combine with the tester. The F_4 lines of DRGR 24 187 x DRGR 32 100 combined better with the DH 7335 (CT_3) / C as evidenced by the eight dF_1 of this figured in the top rank C1 *viz.*, RGR 8, RGR 13, RGR 12, RGR 20, RGR 28, RGR 4, RGR 18 and RGR 49 (Fig. 6) and similarly 13 dF_1 *viz.,* RSG 18, RSG 23, RSG 6, RSG 25, RSG 27, RSG 47, RSG 31, RSG 7 RSG 28, RSG 9, RSG 33, RSG 11 and RSG 37 in case of the F_4 lines of DSMR 10 x DSG 3 5 of this figured in the top rank D_1 (Fig. 7) .

Based on graphical presentation given for diverse tester it was evident that the lines of two populations revealed a larger variability for ability to combine with the tester. The F_4 lines

Fig. 3: Combining ability status of F_4 lines of population I based on cross performance with Stay tester DSG35

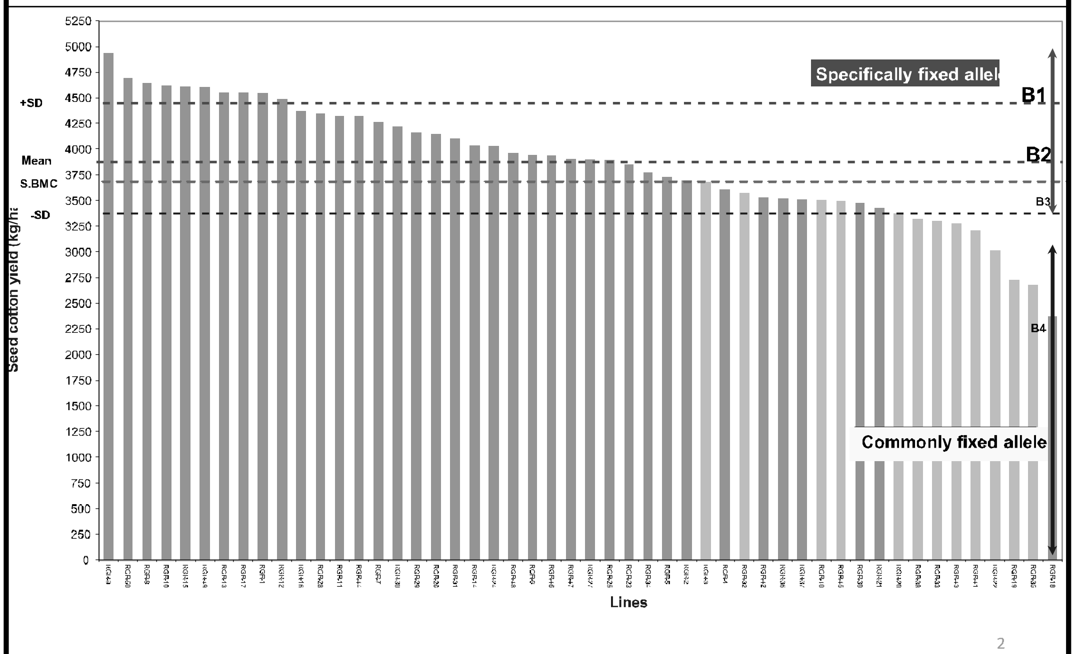
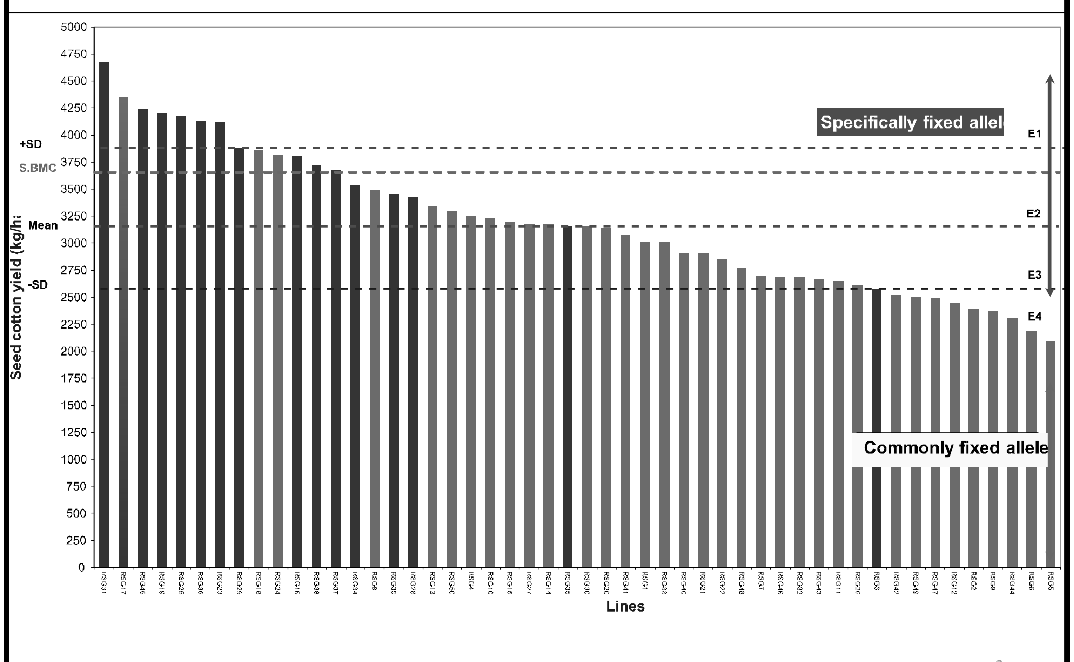
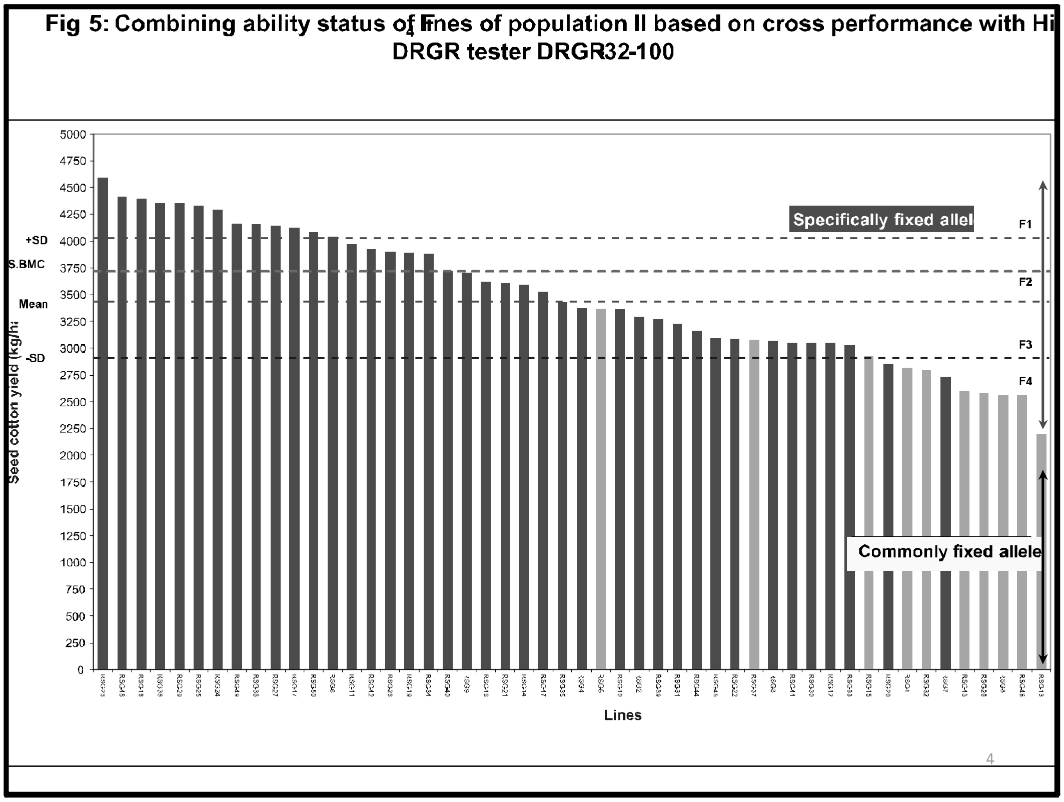


Fig 4: Combining ability status of F_4 lines of population II based on cross performance with High tester DRGR24-178





of DRGR 24 187 x DRGR 32 100 combined better with the DR 8 (DT_4) / G as evidenced by the higher frequency of crosses falling under the category G 1 (Fig. 8) *viz.*, RGR 30, RGR 23, RGR 34, RGR 22, RGR 13, RGR 47 and RGR 50. In case of population II, F_4 lines of DSMR 10 x DSG3 5 *viz.*, RGR 45, RGR 20, RGR 23, RGR 37, RGR 17, RGR 18, RGR 9, RGR 22, RGR 25, RGR 48 and RGR 6 found in higher combiner category (H1) against the diverse tester DRGR 4 (DT_8) /H (Fig 9).

In another form of graphical representation shown in Figures. Two testers

Table 3. Distribution of transgressive segregants of high RGR F_4 lines of DRGR 24 178 x DRGR 32 100 against reciprocal tester

	Positive transgressive segregants above the mean value	
Sl. No.	Lines	Classes
1	RGR 8	A1B1
2	RGR 50, RGR 10, RGR 12, RGR 13	A1B2
3	RGR 28, RGR 30, RGR 07, RGR 27, RGR 23	A2B1
4	RGR 46, RGR 29, RGR 11, RGR 14, RGR 24, RGR 44, RGR 26, RGR 48	A2B2
Negative transgressive segregants		
5	RGR 19	A4B4

Table 4. Distribution of transgressive segregants of robust stay green (RSG) F_4 lines of DSMR 10 x DSG3 5 against reciprocal tester

	Positive transgressive segregants above the mean value	
Sl. No.	Lines	Classes
1	RSG 23, RSG 29, RSG 18, RSG 25, RSG 36, RSG 17,	E1F1
2	RSG 19	E1F2
3	RSG 38, RSG 24,	E2F1
4	RSG 16, RSG 34, RSG 28, RSG 50	E2F2
Negative transgressive segregants		
5		E4F4

Fig.6: Combining ability status of F_4 lines of population I based on cross performance with Com tester DH-7225

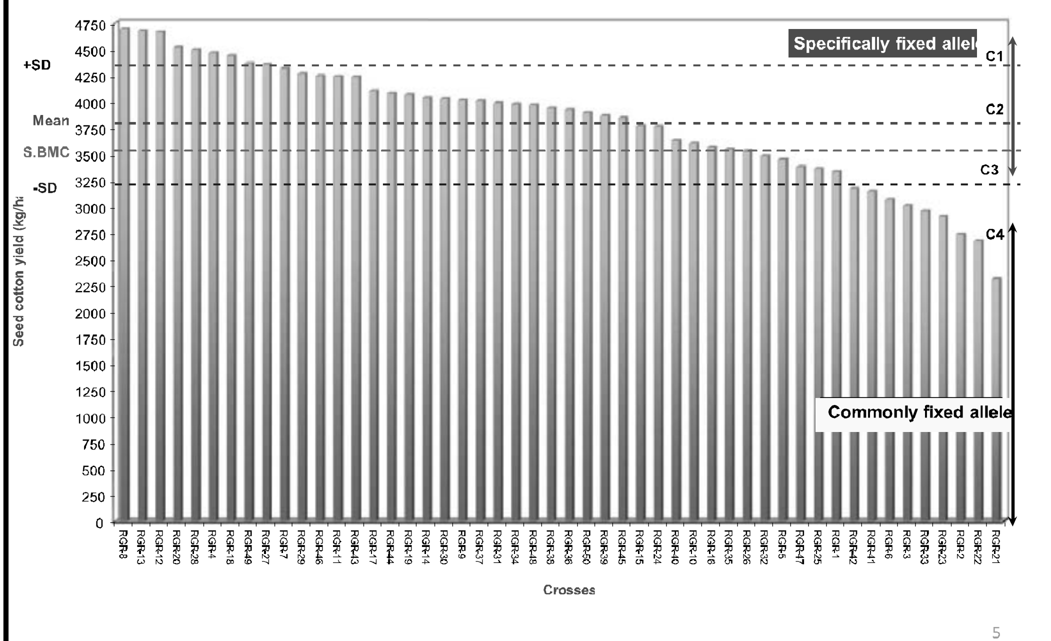


Fig 7 : Combining ability status of F_4 lines of population I based on cross performance with Div tester DRCR8

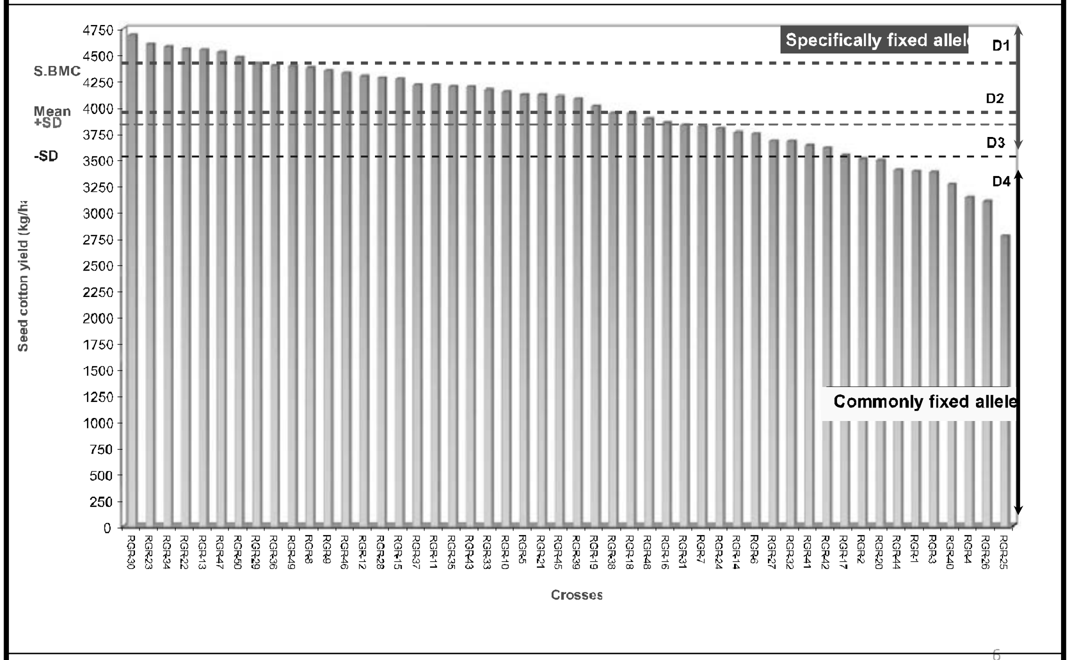


Fig.8 : Combining ability status of F_4 lines of population II based on cross performance with Con tester DH-7225

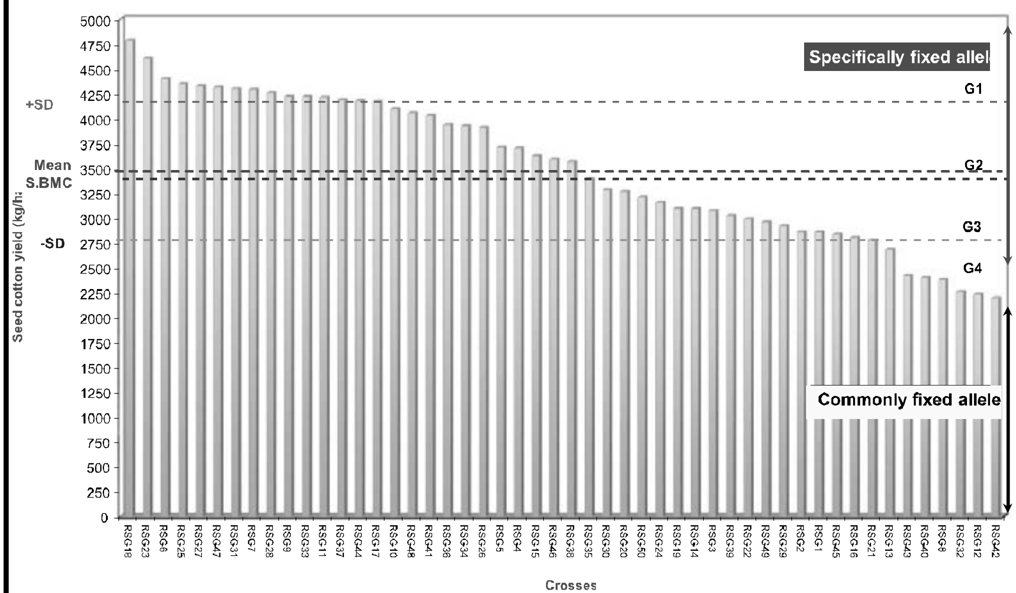


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Fig. 9 : Combining ability status of F_4 lines of population II based on cross performance with div RGR tester DRCR-4

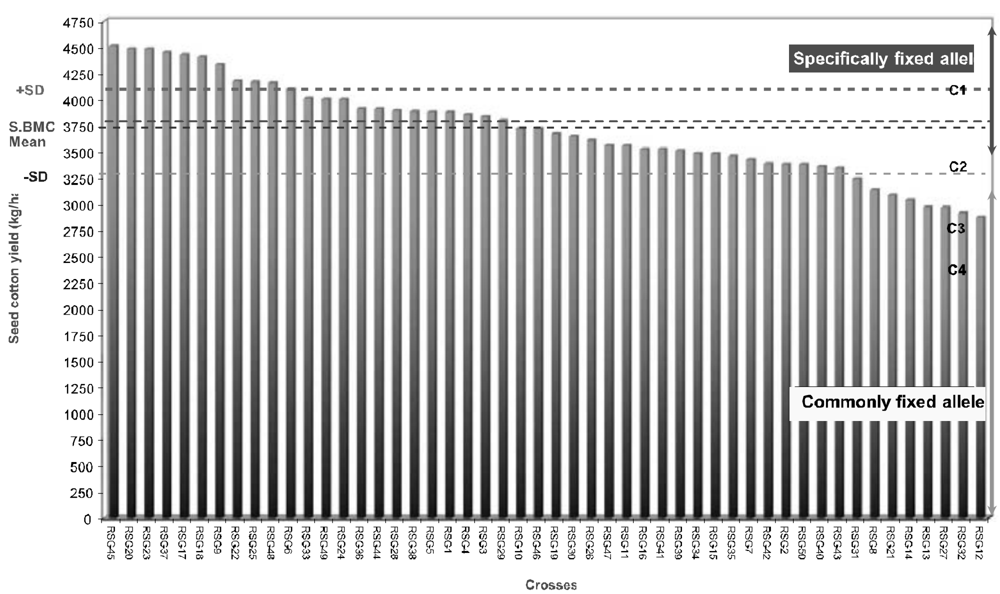

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Fig. 10 Sub-grouping of F_4 lines of population I based on cross performance against two Robust/Stay Green reciprocal testers (DSMR-10 and DSG3-5)

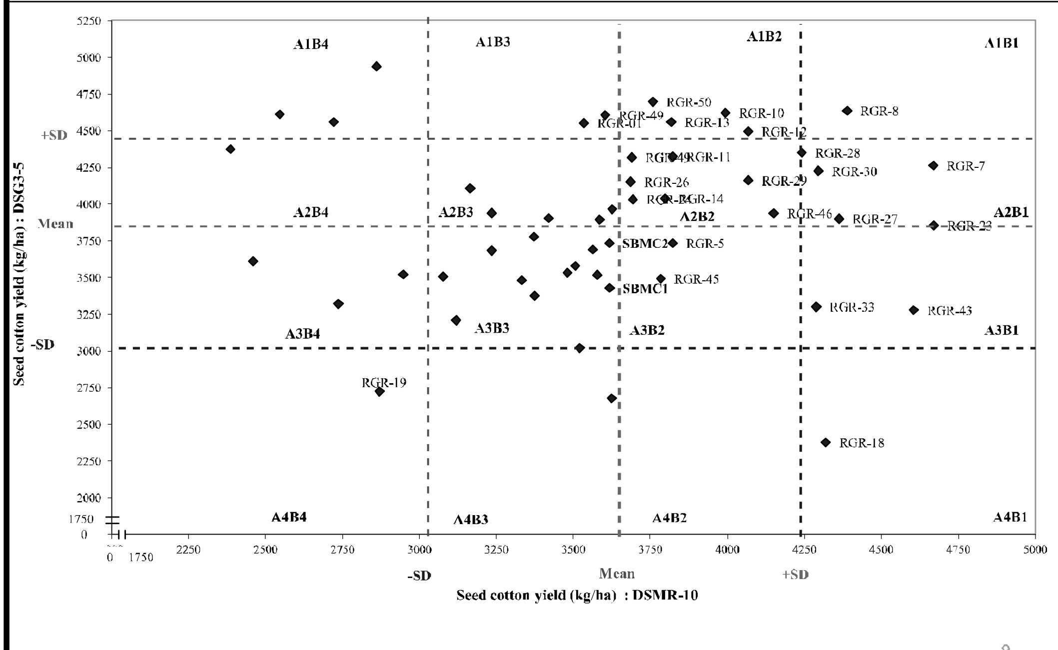
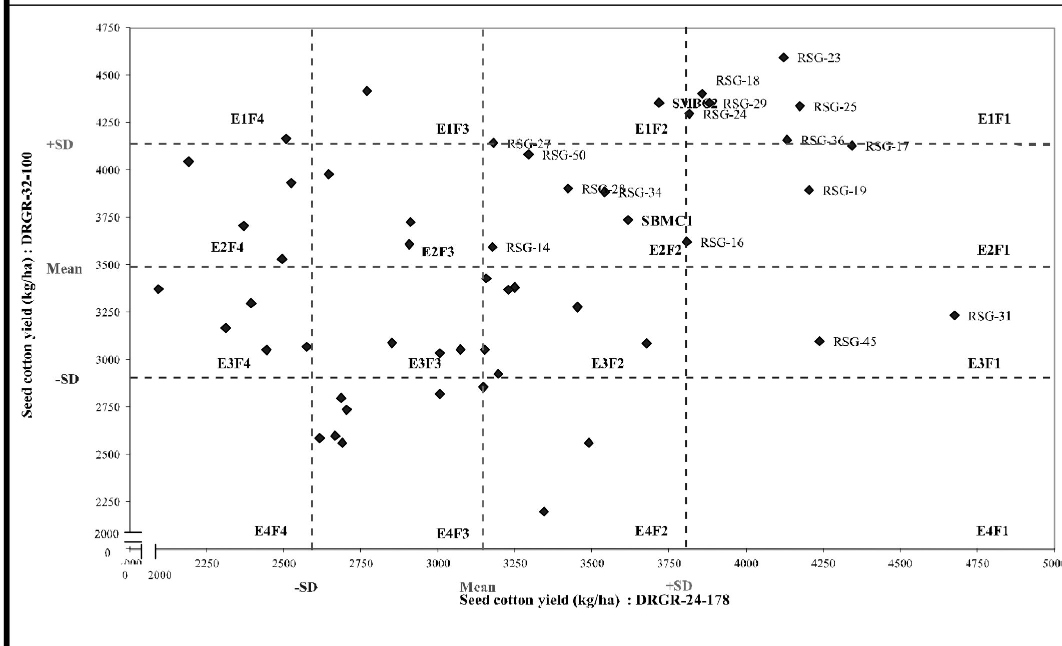


Fig. 11 : Sub-grouping of F_4 lines of population II based on cross performance against two High RGR reciprocal testers (DRGR-24-178 and DRGR-32-100)



can be chosen for representation, one on each axis. Here it has been shown by utilizing the F_1 performance of from pop I and II with the reciprocal and common and diverse testers inducted in the study. This form of representation helps in identifying the falling genotypes in 16 sub groups formed in each graph. The falling genotypes in AlBl similarly C1Dl, E1F1 and G1F1 subgroups represent the most potential combiners against the tester combinations concerned. In the same graph the mean performance of each sub group against the testers is depicted. Further, the scoring patterns of the are given and the top five crosses are marked from examining the combining ability pattern of the lines involved in the best crosses.

It is possible to choose revealing high combining ability against a particular chosen tester. Such chosen can be involved in developing sub population for improving combining ability against the chosen tester (s). For example, if the objective is to improve combining ability against RT_1, the representing A1 sub group can be utilized in developing A1 sub population which will recombine and accumulate favourable alleles for giving superior performance against RT_1.

Based on the graphical presentation given for tester DSMR 10 (RT_1) /A and DSG3 5 (RT_2) / B (Fig 10), A1 is a class of lines which are more diverse to the reciprocal tester DSMR 10 (RT_1) and B1 is the class of lines which are more diverse to the another reciprocal tester DSG3 5 (RT_2). They have accumulated highest number of specifically fixed favourable allele in those respective F_4 lines. whereas, A1B1 is the class of lines which are simultaneously diverse to the both the reciprocal tester. It is evident that line *viz.,* RGR 8 was belong to class of A1B1 revealed large variability for ability to combine with these two reciprocal testers (Table 3). Similarly in the graphical representation of tester DRGR 24 178 (RT_5) /E and DRGR 32 100 (RT_6) / F (Fig. 11). E1F1 is the class of lines which are simultaneously diverse to the both the reciprocal tester. It is evident that lines RSG 23, RSG 29, RSG 18, RSG 25, RSG 36, RSG 17 were belong to class of E1F1 revealed large variability for ability to combine with these two reciprocal tester (Table 4). Whereas the graphical representation of common tester DH 7225 (CT_3) /C and diverse tester DR 8 (DT_4) / D against high RGR F_4 lines

Table 5. Distribution of transgressive segregants of high RGR F_4 lines of DRGR 24 178 x DRGR 32 100 against common (DH 7225) and diverse tester (DR 8)

Sl. No.	Positive transgressive segregants above the mean value — Lines	Classes
1	RGR 13	C1D1
2	RGR 30, RGR 34, RGR 50	C1D2
3	RGR 8, RGR 49, RGR 12, RGR 28, RGR 12, RGR 49	C2D1
4	RGR 46, RGR 29, RGR 11, RGR 19, RGR 9, RGR 37, RGR 36, RGR 39, RGR 45	C2D2
Negative transgressive segregants		
5	RGR 3 and RGR 2	C4D4

Table 6. Distribution of transgressive segregants of robust stay green (RSG) F_4 lines of DSMR 10 x DSG3 5 against common (DH 7225) and diverse tester (DR 8)

Sl. No.	Positive transgressive segregants above the mean value — **Lines**	**Classes**
1	RSG 18, RSG 23, RSG 25	G1H1
2	RSG 37, RSG 17, RSG 9	G1H2
3	RSG 6, RSG 28	G2H1
4	RSG 33, RSG 44, RSG 10, RSG 48, RSG 36, RSG 5, RSG 4, RSG 46, RSG 38	G2H2
Negative transgressive segregants		
5	RSG 21, RSG 13, RSG 8, RSG 32, RSG 12	G4H4

Fig. 12 : Sub-grouping of F_4 lines of population I based on cross performance against common (DH-7225) and diverse (DRCR-8)testers

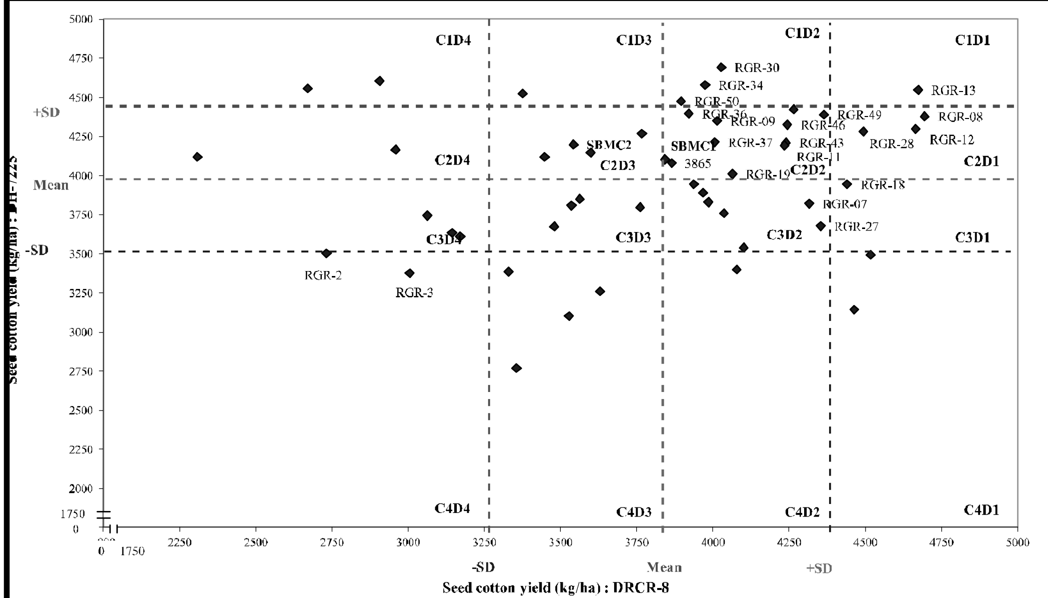


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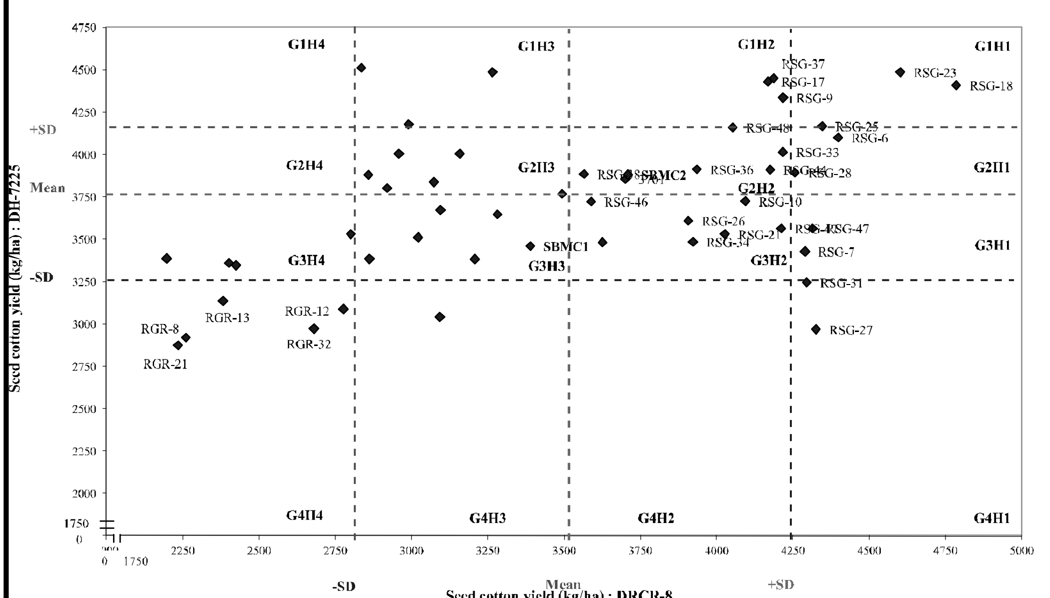
Fig. 13: Sub-grouping of F_4 lines of population II based on cross performance against common (DH-7225) and diverse (DRCR-4) testers



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(Fig 11) grouped in C1D1 class of lines which are simultaneously diverse to both common and diverse tester. It is evident that line RGR 13 was belong to class of C1D1 revealed large variability for ability to combine with these common and diverse tester (Table 5). This suggest that this first class line can recombined with other potential lines to initiate second phase of creating recombinational variability for combining ability.

With respect to the population II, the graphical representation of common tester DH 7225 (CT_7) /G and diverse tester DRGR 4 (DT_8) / H against robust and stay green F_4 lines (Fig. 13) grouped in G1D1 class of lines which are simultaneously diverse to the both common and diverse tester. It is evident that lines RSG 18, RSG 23 and RSG 25 were belong to class of G1H1 revealed large variability for ability to combine with these common and diverse tester (Table 6). This also suggested that these first class lines can recombined to initiate second phase of creating recombinational variability for combining ability.

CONCLUSION

In routine population improvement scheme meant for improving combining ability there are three steps namely a) Selfing b) Evaluation of the elite combiners c) Recombining the elite combiner. The principle of population improvement for combining ability has been extended in this study to a self pollinated crops. Analysis of variance of results revealed what are good combiner F_4 lines of the population for individual testers and also pairs of testers. The elite combiners whose derived F_1's revealing seed cotton yield more than Mean + 1 Standard Deviation are identified and it is likely that lines belonging to this elite group may differ with respect to identity of dominant favorable allele present in them. Hence the next course of action should be recombine elite combiners to develop a new population to initiate the next cycle of reciprocal recurrent selection against a single testers or combination of testers.

The elite high combiner lines identified from opposite populations are expected to be genetically diverse. Hence the crosses obtained from these elite combiners are expected to be potential. The elite sub populations give scope for further enhancement of genetic distance between the groups and paves way for the next phase of improvement in hybrid performance. With this presumption the elite high RGR F_4 lines of DRGR 24 178 x DRGR 24 178 *viz.*, RGR 23, RGR 7, RGR 43, RGR 8, RGR 27, RGR 9, RGR 50, RGR 10, RGR 15 and RGR 49 and the robust stay green elite F_4 lines of DSMR 10X DSG3 5 opposite population *viz.,* RSG 31, RSG 17, RSG 45, RSG 19, RSG 25, RSG 23, RSG 48, RSG 18, RSG 38 and RSG 29 were selected on the basis of derived F_1s performance and the ten elite combiners each from the opposite groups will be crossed in line x tester fashion to get new improved derived F_1s.

The trangressive segregants distributed in population I and II were classified in to positive and negative transgressive segregants based on the sub grouping of F_4 lines with respect to reciprocal tester, common and diverse testers respectively where positive transgressive segregants are showing positive gca effect with the opposite parents hence they combined well the both parents. There are array of lines which combine well with single parent and is due to the recombination of allele which favouring P_1 or P_2 alone. Similarly negative transgressive segregants are those which are showing significant negative *gca* effect with the opposite parent.

REFERNCES

Anonymous, 2014. All India Coordinated Cotton Improvement Project, *Annu. Rep.,* 2013 2014, **1** : 1-10.

Falconer, D. S., 1981. *Introduction of Quantitative Genetics*, Longman Inc. Ltd., New York.

Patil, S. S., 1995. *Report on the Work Done in the Area of Hybrid Research CIMMYT*. The International maize and Wheat Improvement centre El Batan, Mexico.

Patil, S. S., Patil, S. A., Ramakrishna, V., Deepakbabu, H. and Mallikarjun, H. B., 2007. Approaches of improving combining ability for enhancing performance of cotton hybrids. *Fourth World Cotton Research Conference*, 10-11th September 2007, *Lubbock*, Texas, USA.

Pranesh, K. J., 2014, Exploiting heterotic groups through reciprocal recurrent selection for combing ability to improve performance of cotton hybrids, *Ph. D. Thesis*, Univ. Agric. Sci, Dharwad, Karnataka.

Ramakrishna, V., 2008. Reciprocal selection for improving combining ability in cotton. *Ph. D. Thesis*, Univ. Agric. Sci, Dharwad, Karnataka (India).

Genetical and biochemical basis of cotton leaf curl disease in upland cotton

ANURADHA GODARA, S .S. SIWACH, R. S.SANGWAN AND S. MANDHANIA

Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125 004

E-mail : anu.godara@yahoo.co.in

ABSTRACT : The present investigation comprising six generations (Parents, F_1, F_2, BC_1 and BC_2) of four crosses in cotton *viz.,* H1098-I x B 59-1678, H 1117 x HS6, H 1098-I x H1117 and B 59-1678 x HS6 was conducted for studying the inheritance of cotton leaf curl virus disease and estimating the gene effects for the yield and its component traits during *kharif,* 2013. The inheritance of cotton leaf curl virus disease indicated the duplicate dominant epistasis(15:1). Generation mean analysis revealed significant differences for all traits indicating thereby the presence of non-allelic interactions. In some of the cases, the non-significance of chi-square value indicated the fitness for additive-dominance model. Additive component was significant for most of the characters and even as preponderant in magnitude over the dominance component. Either all or any of the three types of epistatic interactions (i, j and l) were significant for most of the cases and generally it is the "i" type of interaction which is more frequently prevailing for most of the traits studied over the crosses. Additive x additive type of interaction was recorded for plant height, boll number, boll weight, GOT, seed index and seed cotton yield. Duplicate type of interaction was apparent for plant height, boll number, boll weight, GOT and lint index. Among biochemical parameters, sugar content was higher in susceptible parents than resistant ones. Also, it decreased at 90 DAS when the disease incidence was higher and further increase at 120 DAS. Phenol, tannin and gossypol content, the secondary metabolites were higher in resistant parents as compared to susceptible parents. Concentration was more at 90 DAS which decrease at 120 DAS. Correlation matrix indicated that cotton leaf curl virus disease grading was significant positively correlated with the sugar content and negatively correlated with phenol, tannin, gossypol, protein and cellulose.

Cotton as a crop as well as commodity plays an important role in the agrarian and industrial activity of the nation and has a unique place in the economy of our country. Cotton is grown in tropical and sub-tropical regions of more than 80 countries world over while leading cotton producing countries are China, India, USA, and Pakistan (Meyer *et al.*, 2013).

Cotton is the most important *kharif* cash crop of north India. In Haryana only *G. hirsutum* and *G. arboreum* species are grown. More than 90 per cent area of cotton is under *G. hirsutum.* Main reasons for low productivity of cotton in India attributed to the high incidence of insect pests and diseases caused by fungal, bacterial and viral pathogens. Of these viral diseases alone or in combination with other factors are quite destructive and are limiting factor for the cotton cultivation resulting significant loss in seed cotton yield.

The diseases caused by geminiviruses are of considerable concern. Among various geminiviruses cotton leaf curl virus disease CLCuD is the most devastating disease in cotton. In India, cotton leaf curl virus disease was first reported in American cotton (*G hirsutum*) in Sriganganagar area of Rajasthan state during 1993 (Ajmera,1994) and during 1994 it appeared in Haryana and Punjab (Rishi and Chauhan,1994;Singh *et al.*,1994) states on *hirsutum* cotton and posed a major threat to its cultivation in northern India (Varma *et al.*,1995). The disease has appeared in an epidemic form during 1997 in the Rajasthan affecting an area of 0.1 million hectares (Anonymous,1998).

Use of chemicals in controlling the whitefly (the vector of this virus) is costly and not so effective. Moreover, it may be hazardous to men and environment. Extensive uses of pesticides have also caused damage to soil quality and fertility (Dinham, 1993). Therefore, development of a resistant variety to this disease is the most effective, long term, less expensive and safe method to fight against this disease and to enhance the productivity of cotton. Research efforts to develop resistant varieties/ hybrids through conventional/ biotechnological approaches along with cultural and management practices are in progress for effectively controlling this disease.

Nature has provided cotton with traits like okra leaf type, gossypol glands and trichomes which confer non-preference to the insect pest infestation. The information on various biochemical parameters imparting resistance to cotton leaf curl virus disease will help for identification of resistant varieties based on biochemical attributes and same can be used as early selection criterion for screening germplasm and other breeding material.

In order to achieve this goal, an understanding of mode of inheritance of cotton leaf curl virus disease and seed cotton yield along with other biochemical parameters (responsible for resistance to cotton leaf curl disease) is necessary for proper choice of breeding procedures.

MATERIALS AND METHODS

The present investigation was conducted at Cotton Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif,* 2013. Four parents two resistant (H 1098I and H 1117) and two susceptible (B 59-1678 and HS 6) to cotton leaf curl virus disease were chosen to generate the experimental material. These four parents were used to develop four crosses, H 1098-I x B 59-1678 (R x S), H 1117 x HS 6 (R x S), H 1098-I x H1117(R x R) and B 59-1678 x HS 6 (S x S). These crosses were designated as cross I, cross II, cross III and cross IV, respectively and finally six generations were generated *i.e.* P_1, P_2, F_1, F_2, BC_1 and BC_2. The experimental material comprised of six generations *i.e.* parents (P_1 and P_2), F_1, F_2 and back crosses (B_1 and B_2) of four crosses was grown in a compact family block design with three replications. There was a single row of non segregating generations (P_1, P_2 and F_1), 20 rows of F_2, and 8 rows of each BC_1 and BC_2 generations. The length of each row was being 6 m with a spacing 67.5 x 30 cm. In order to build up heavy inoculums pressure one row of highly susceptible line (HS 6) was planted at the periphery of the experimental area.

Observation on CLCuD was recorded under field condition in each replication on all the plants of each of the non –segregating generations (P_1, P_2 and F_1), backcross generations and the F_2 generation. Disease was scored on 0 -5 grade depending upon the response to the cotton leaf curl virus disease CLCuD.

$$\text{Per cent disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

0= Immune; complete absence of symptoms, per cent disease incidence = 0

1= Highly resistant; very minute thickening of veins, per cent disease incidence = 0 – 10

2= Resistant; thickening of small group of veins, per cent disease incidence=10–20

3= Susceptible; severe vein thickening and leaf curling developed at the top of the plant, per cent disease incidence=20- 40

4= Moderately susceptible; severe vein thickening and leaf curling developed on the half of the plant canopy, per cent disease incidence = 40 - 70

5= Highly susceptible; severe vein thickening, leaf curling, enation and full stunting of plant, per cent disease incidence = 70 – 100

Five competitive plants from each row of non – segregating generations and 30 plants from F_2 generation and 10 plants from each of backcrosses were chosen at random for recording observations on the following economic characters: days to first flower, plant height, no. of bolls / plant, boll weight, ginning outturn, seed index, lint index and seed cotton yield/plant

Biochemical study was carried out in biochemistry laboratory of Cotton Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar. Total phenols, total sugars, tannins, crude proteins, total gossypol and structural carbohydrates were analyzed using their standard methods. The healthy leaves as well as diseased leaves of all four crosses were taken at three stages of plant growth i.e. vegetative stages (60 DAS), reproductive stage (90 DAS) and maturity stage (120 DAS).

Statistical Analysis

The Chi – Square test of goodness of fit

$$\chi^2 = i = \sum_{1}^{n} \frac{(Oi - Ei)^2}{Ei}$$

Whereas;

O_i = observed frequency of i^{th} class

E_i = expected frequency of i^{th} class

For testing the significance, the c^2 tabulated values were seen at n-1 d.f.

Biometrical analysis for Estimation of Gene Effects : The "t" statistical test was applied to test the differences between parental genotypes for the studied characters before considering the biometrical analysis. The gene effects were estimated by employing generation mean analysis of Mather (1967), Hayman and Mather (1955) and Jinks and Jones (1958).

RESULTS AND DISCUSSION

The incidence of cotton leaf curl virus disease during the experimental year *i.e.* 2013-2014 was very severe under field condition particularly nearby Hisar areas including CCS HAU, cotton research area. During this year no variety/ strain was observed completely immune to this disease. Even in highly resistant strains only few plants showed immunity. The F_1s *viz.,* H 1098-I x B 59-1678 and Cross H 1117 x HS 6 had resistance to CLCuD indicated that resistance is a dominant trait. The expression of resistance in both (R x S) crosses revealed

Table 1. Inheritance of CLCuD in upland cotton

Parent/ generation	Number of plants Screened	Resistant	Susceptible	Expected ratio	a”2 calculated	P value
Cross I (R x S): H 1098-I x B 59-1678						
P_1	54	54	0			
P_2	56	0	56			
F_1	61	61	0			
F_2	364	348	16	15:1	2.27	0.131
BC_1	218	218	0			
BC_2	243	173	70	3:1	1.77	0.183
Cross II(R x S):Cross H 1117 x HS 6						
P_1	61	61	0			
P_2	57	0	57			
F_1	59	59	0			
F_2	358	331	27	15:1	0.74	0.389
BC_1	221	221	0			
BC_2	231	168	63	3:1	0.575	0.448
Cross III (R x R): H 1098-I x H1117						
P_1	54	54	0			
P_2	59	59	0			
F_1	58	58	0			
F_2	347	347	0			
BC_1	236	236	0			
BC_2	221	221	0			
Cross IV(S x S): 59-1678 x HS 6						
P_1	59	0	59			
P_2	59	0	59			
F_1	56	0	56			
F_2	358	0	358			
BC_1	230	0	230			
BC_2	235	0	235			

that there was no cytoplasmic inheritance for the expression of susceptibility to CLCuD. The dominance nature of resistance over susceptibility was further confirmed by backcrosses and F_2s. The pattern of segregation in F2 gave a good fit to 15 resistant: 1 susceptible (Table 1) indicating the duplicate type of gene action. Disease was expressed in those plants which had recessive genes at both the loci. Duplicate type of gene interaction for CLCuD was further confirmed by a good fit of 3 resistant: 1 susceptible ratio of backcross with susceptible parents.

The breeding for cotton leaf curl disease resistance has been achieved through the assemblage of minor genes by recurrent selection and according to Azhar *et al.*(2010) resistance depends on major genes (dominant genes) which may lose quickly because of the evolution of pathogen for these genes. The F_1 of crosses between highly susceptible S 12, highly resistant LRA 5166 varieties were found all virus free plants and their F_2 was close to 3:1 ratios which exhibit the presence of a single gene for the inheritance of resistance against CLCuD reported by Rehman *et al.,* (2005). Ahuja *et al.*, 2006 reported 4 types of segregation patterns in the F_2 generations. A good fit for 15 (resistant):1

(susceptible), 13 (resistant):3 (susceptible), 9 (resistant):7 (susceptible) ratios indicated digenic control of the trait with duplicate dominant, dominant inhibitory, and duplicate recessive epistasis, respectively. Three gene controls with triplicate dominant epistasis was obtained in one of the crosses.

In F2 generation of cross H 1098-I x H1117 (R x R), all the plant were resistant resistant to CLCuD indicated that genes involved in the resistance of CLCuD were present at the same locus in both the parents. Hence no segregation pattern was observed in F2 and backcrosses. In cross 59-1678 x HS 6 (S x S), all the plants in F1, F2 and backcross generations were susceptible to CLCuD. The disease reaction in all generations was similar to the reaction of parents suggesting that there was no complimentary interaction between the genes for susceptibility in both the susceptible parents.

Estimation of epistasis: The joint scaling test of Cavalli (1952) has indicated the adequacy of simple additive-dominance model for days to first flower in cross I, II and III, 100 seed weight (cross III), lint index (cross III) and seed cotton yield in crosses I, III and IV. Additive effects for seed cotton yield and its attributing characters were also reported by Kaushik and Kapoor, (2006), Abbas *et al.*, (2008), Ali *et al.*, (2009), Lu and Myers, (2011) and Iqbal *et al.*, (2013). This suggested that the additive gene effects played important role in the inheritance of all these attributes and simple selection would be adequate to improve such characters.

The characters under study which could not be explained on simple additive-dominance model as tested through scaling tests were analyzed on digenic epistatic model of Hayman (1958). The estimates of mean (m), additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) were estimated from six generations i.e. P_1, P_2, F_1, F_2, BC_1 and BC_2.

For those characters, where digenic model has been found as adequate, largely the characters have been observed where there has been preponderance of both 'additive' and 'dominance' components and among epistatic components mostly 'i' type (additive x additive) and 'l' type (dominance x dominance) epistatis contributed significantly towards the gene effects. Moreover, in some other situations either 'i-type' epistatis alone or 'i-type' epistatis in combination with 'j-type' epistatis or all the three types of epistatis were found significantly contributing to the gene effects. It is interesting to note that 'j' type of epistasis alone has been reported only in few cases viz. seed index (cross IV), lint index (cross II and IV). Preponderance of additive x additive (i-type) epistasis or gene interaction suggested that such traits in the population maybe improved through random mating of the selected desirable plants followed by selection. This approach will lead to the exploitation of additive (d); additive x additive (i-type) of gene effects and interactions in the populations. The high frequency of occurrence of dominance (h) and dominance x dominance (l-type) gene effects and interactions may paradoxically suggest the exploitation of heterosis in cotton. However, a close examination for the sign of 'h' and 'l' type of epistatis reveal that magnitude of the two if found in opposite direction than contribution to the phenotypic mean imply thereby antagonistic effects in heterosis expression and it has been termed as 'duplicate' type of epistasis which may be explained on the basis of fact that majority of the parents involved in the cross were selections towards a single optimum phenotype and as such it is this selection for optimum type that has

Table 2(a). Generation mean analysis for yield attributing traits in different crosses of upland cotton

Characters	Parameter	Cross I (H1098-I x B59-1678)	Cross II (H 1117 x HS 6)	Cross III (H 1098-I x H 1117)	Cross IV (B59-1678 x HS 6)
Days to first flower	**Joint scaling test (three parameter model)**				
	m	55.77**±0.36	56.87**±0.55	55.63**±-0.42	54.95**±0.39
	d	1.04**±0.33	0.18±0.54	0.73±0.41	-0.47±0.37
	h	-0.01±0.69	0.34±1.02	0.20±0.79	0.36±0.76
	÷^{2}(df=3)	**4.98**	**3.03**	**0.63**	**8.39****
	Six parameter model				
	m	56.02**±0.30	57.10**±0.33	55.88** ±0.31	55.65**±0.31
	d	-0.93±0.61	-0.60±0.91	0.07± 0.34	0.000±0.60
	h	-0.85±1.89	-2.00±2.49	-1.28±2.12	4.02±1.93
	i	-0.22±1.74	-2.53±2.26	-1.48±1.95	-4.35±1.75
	j	0.20±1.48	-0.93±2.29	-0.46±1.79	-1.86±1.55
	l	-3.44±3.13	7.06±4.41	2.48±3.62	7.82±3.17
	Type of epistasis	-	-	-	-
Plant height	**Joint scaling test (three parameter model)**				
	m	131.94**±1.43	138.27**±1.68	136.58**±1.34	129.22**±1.28
	d	-21.28**±1.46	-6.02**±1.69	-5.08**±1.37	13.91**±1.31
	h	-1.28±2.38	-6.29±3.21	-2.28±2.33	-7.22**±2.17
	÷^{2}(df=3)	**27.17****	**146.57****	**442.82****	**272.76****
	Six parameter model				
	m	128.88**±2.05	117.81**±2.16	107.36**±2.49	102.51**±2.15
	d	15.60**±3.73	3.33±4.58	22.56**±5.86	-11.80*±5.09
	h	-20.75±11.35	45.72**±13.04	2.60±15.57	6.52±13.51
	i	-20.08±11.09	40.75**±12.60	-2.33±15.39	8.75±13.33
	j	-8.66±8.16	-0.60±9.89	42.20**±12.07	1.53±10.54
	l	64.62**±17.70	45.04*±21.36	170.66**±25.92	115.31**±22.54
	Type of epistasis	Duplicate	Complimentary	-	-
Boll number	**Joint scaling test (three parameter model)**				
	m	13.09**±0.36	14.57**±0.56	14.39**±0.43	11.98**±0.48
	d	1.99**±0.36	3.50**±0.51	0.33±0.45	-0.42±0.45
	h	6.16**±0.85	4.05**±1.19	4.73**±0.79	8.29**±1.06
	÷^{2}(df=3)	**10.76****	**13.68****	**8.63****	**13.67****
	Six parameter model				
	m	16.34**±0.57	16.30**±0.54	16.20**±0.46	15.46**±0.55
	d	2.30*±1.09	6.66**±1.05	-0.86±1.52	1.86±0.96
	h	8.45*±3.32	8.63*±3.41	14.63**±3.66	12.90**±3.26
	i	4.15±3.16	3.06±3.02	10.00*±3.57	6.66*±2.94
	j	0.66±2.32	8.33**±2.41	-1.26±3.20	3.80±2.18
	l	-14.02*±5.36	-1.40±5.69	-18.33*±6.58	-15.93**±5.25
	Type of epistasis	Duplicate	-	Duplicate	Duplicate
Boll weight	**Joint scaling test (three parameter model)**				
	m	3.53**±0.03	33.82**±0.17	3.43**±0.04	3.00**±0.04
	d	-0.39**±0.03	-0.13±0.16	-0.42**±0.04	0.05±0.04
	h	-0.23**±0.07	-2.73**±0.37	-0.32**±0.08	-0.19*±0.07
	÷^{2}(df=3)	**72.19****	**31.88****	**17.63****	**8.54****
	Six parameter model				
	m	3.39**±0.08	2.98**±0.03	3.32**±0.04	3.08**±0.31
	d	0.31**±0.08	-0.12*±0.05	0.55**±0.10	-0.28±0.13
	h	-1.05**±0.38	-0.72**±0.22	-1.02**±0.28	-1.07±1.29
	i	-0.99**±0.37	-0.32±0.18	-0.72**±0.26	-0.91±1.29
	j	-0.09±0.19	0.10±0.16	0.41±0.22	-0.53±0.29
	l	2.93**±0.50	1.71**±0.35	1.54**±0.47	1.30±1.38
	Type of epistasis	Duplicate	Duplicate	Duplicate	

Table 2(b). Generation mean analysis for yield attributing traits in different crosses of upland cotton

Characters	Parameter	Cross I (H1098-I x B59-1678)	Cross II (H 1117 x HS 6)	Cross III (H 1098-I x H 1117)	Cross IV (B59-1678 x HS 6)
Ginning Outturn	**Joint scaling test (three parameter model)**				
	m	34.3**±0.10	34.44**±0.14	33.97**±0.23	33.82**±0.17
	d	-0.99**±0.10	-0.56**±0.13	-0.05±0.22	-0.13±0.16
	h	-0.44±0.22	-1.30**±0.29	0.63±0.41	-2.73**±0.37
	$\div^2$(df=3)	**23.64****	**12.99****	**17.33****	**31.88****
	Six parameter model				
	m	34.25**±0.16	33.67**±0.20	43.85**±0.17	31.77**±0.17
	d	2.20**±0.34	1.24**±0.24	0.71*±0.28	-0.06±0.41
	h	-2.08*±0.98	-0.17±1.00	3.45*±1.41	1.70±1.19
	i	-1.80±0.95	1.38±0.94	1.72±0.91	3.20**±1.10
	j	2.74**±0.71	1.82**±0.59	2.82±2.17	-0.43±0.91
	l	3.63*±1.59	2.95*±1.43	-1.72±2.55	-0.01±2.03
	Type of epistasis	Duplicate	-	-	-
Seed index	**Joint scaling test (three parameter model)**				
	m	7.45**±0.04	7.27**±0.06	7.34**±0.05	7.17**±0.05
	d	-0.77**±0.04	0.48**±0.06	-0.59**±0.05	0.60**±0.04
	h	0.36**±0.09	0.52**±0.10	-0.22*±0.09	0.48**±0.10
	$\div^2$(df=3)	**20.65****	**31.68****	**4.05**	**15.23****
	Six parameter model				
	m	7.89**±0.07	7.41**±0.07	7.29**±0.06	8.29**±0.71
	d	0.58**±0.10	-0.25±0.13	0.72**±0.13	-0.15±0.13
	h	-1.09**±0.37	0.22±0.40	-0.26±0.38	-2.79±2.85
	i	-1.42**±0.36	-0.31±0.39	-0.02±0.36	-3.18±2.85
	j	-0.45±1.76	0.63*±0.29	0.28±0.29	1.01**±0.29
	l	1.76**±0.55	1.96**±0.63	-0.46±0.62	2.66±2.90
	Type of epistasis	Duplicate	-	-	-
Lint index	**Joint scaling test (three parameter model)**				
	m	3.93**±0.03	3.82**±0.03	3.77**±0.06	3.68**±0.03
	d	-0.59**±0.03	0.14**±0.03	-0.35**±0.06	0.27**±0.03
	h	0.08±0.06	-0.04±0.06	-0.03±0.11	-0.05±0.07
	$\div^2$(df=3)	**17.49****	**24.23****	**6.21**	**7.11**
	Six parameter model				
	m	4.12**±0.05	3.77**±0.04	3.73**±0.03	3.85**±0.32
	d	0.68**±0.08	0.08±0.08	0.49**±0.08	-0.08±0.08
	h	-0.92**±0.27	0.05±0.26	0.42±0.27	-0.98±1.32
	i	-1.02**±0.26	0.05±0.25	0.30±0.22	-0.93±1.31
	j	0.22±0.18	0.65**±0.18	0.53±0.32	0.46*± 0.19
	l	1.49**±0.42	0.49±0.40	-0.48±0.48	1.18± 1.36
	Type of epistasis	Duplicate	-	-	-
Seed cotton yield	**Joint scaling test (three parameter model)**				
	m	39.27**±1.40	40.18**±1.55	41.55**±1.39	27.91**±1.20
	d	-11.97**±1.32	-9.73**± 1.33	-3.97*±1.44	0.16±1.17
	h	12.98**±3.05	-0.52±3.28	8.51**±2.54	19.67**±2.69
	$\div^2$(df=3)	**0.41**	**24.65****	**4.39**	**7.17**
	Six parameter model				
	m	45.39**±1.52	38.92**±1.11	44.65**±1.21	37.29**±3.54
	d	13.26**±2.94	16.78**±2.30	6.54±3.43	-0.13±3.24
	h	16.18±9.34	17.66*±8.01	25.42**±8.80	28.64±15.90
	i	2.28±8.48	6.18±6.40	17.07*±8.40	13.18±15.58
	j	3.26±6.60	21.22**±5.67	5.70±7.57	0.22±6.96
	l	-0.40±15.41	20.42±14.07	-31.02*±15.46	-36.42±20.23
	Type of epistasis	-	-	-	-

favoured the duplicate but not the complementary interaction (Mather, 1967). Hence, it is difficult to improve the populations in the presence of duplicate type of epistatis.

Biochemical studies : In recent years, it is becoming increasingly evident that several natural and induced defense mechanisms operate in host plants against different diseases. Sometimes, the host plant is induced to synthesize these compounds on infection. The content of different biochemical constituents viz., sugar content, total phenol, tannin, gossypol, protein and cellulose were estimated at three different growth stages in leaf samples i.e. 60 days after sowing, 90 days after sowing and 120 days after sowing (DAS) in all the four crosses. The results obtained are described as under:-

Table 3. Different biochemical parameters among resistant and susceptible parents at 60 DAS

Parents	Sugar (%)	Phenol (%)	Tannin (%)	Gossypol (%)
H 1098-i	1.43	1.33	0.62	0.50
H 1117	1.20	1.46	0.57	0.48
B 59-1678	2.24	0.80	0.41	0.34
HS 6	3.26	0.78	0.39	0.27
S.E.(m)	0.08	0.04	0.01	0.02
C.D. (p=0.05)	0.25	0.10	0.04	0.05

Sugars acts as precursor for synthesis of phenolics, phytoalexins, lignin and cellulose which play an important role in defense mechanism of plants against invading pathogens (Klement and Goodman, 1967). In the present investigation, sugar content was less in resistant parents (H 1117 and H 1098—I) as compared to that of susceptible parents (B 59 – 1678 and HS 6).

Among major secondary metabolites of different plants, phenols stand out as most important component in imparting resistance to several plant diseases. Higher concentration causes an instant lethal action by a general tanning effect while, lower concentration causes gradual effect on the cellular constituent of the parasite (Dasgupta, 1988). The total phenol content under both the situations (healthy and infected) increased from 60 to 90 DAS. The rate of increase in the total phenol content in response to the CLCuD infection was more in infected plants as compared to healthy ones. This result is in agreement with the findings of Borkar and Verma (1991) in case of cotton against Bacterial blight, Chakrabarty *et al.,* (2002) in case of cotton against Grey mildew, (Govindappa *et al.,* 2008) in case of cotton against bacterial blight.

Tannins are astringent, bitter-tasting plant polyphenols that bind and precipitate proteins. Tannins are considered to be the most important secondary plant compound involved in plant defense against insects and disease (Swain, 1979). In the present investigation, tannin content was higher in resistant plants as compared to susceptible ones. The tannin content under both the situations (healthy and diseased) increased significantly from 60 to 90 DAS and further decreased from 90 to 120 DAS. The rate of decrease in the tannin content in response to the CLCuV infection was more in infected plants as compared to healthy ones. This result is in agreement with the findings of Beniwal *et al.*, (2006) and Acharya and Singh (2008).

Cotton produces a number of toxic terpenoid aldehyde (TA) compounds contained in epidermal glands that help protect the plant from pests and diseases. Gossypol is one of the major TA and its content varied genotypically and with plant age. The gossypol content was 44.69 and

Table 4. Correlation matrix among different biochemical parameters of crosses I: H1098-i x B59-1678 at 60 DAS

Cross I 60 days	CLCuD grading	Sugar	Phenol	Tannin	Gossypol	Protein	Cellulose
CLCuD grading	1.000	0.913**	-0.927**	-0.964**	-0.898**	-0.897**	-0.927**
Sugar		1.000	-0.852**	-0.890**	-0.796**	-0.796**	-0.790**
Phenol			1.000	0.891**	0.767**	0.767**	0.904**
Tannin				1.000	0.866**	0.865**	0.876**
Gossypol					1.000	0.849**	0.836**
Protein						1.000	0.836**
Cellulose							1.000

79.12 per cent was lower in susceptible parents than resistant parents in crosses H 1098-I x B 59-1678 and H 1117 x HS 6 respectively. Also, the gossypol content in both susceptible and resistant plants was increased significantly from 60 to 90 DAS and then decreased from 90 to 120 DAS.

Correlation matrix:

The correlation matrix among different biochemical parameters revealed that with the CLCuD (Cotton Leaf Curl Virus Disease) grading (disease scoring 0-5) and sugar content showed positive significant correlation (Table 4) while other biochemical parameters viz. phenol, tannin, gossypol, protein and cellulose showed significant negative correlation. CLCuD grading did not showed significant correlation with oil content. The same trend was observed in all the four crosses and at different stages of growth.

SUMMARY

The inheritance of cotton leaf curl virus disease indicated the duplicate dominant epistasis(15:1). No complementary gene interaction was observed in cross with susceptible parents for CLCuD resistance.

Scaling tests revealed that additive-dominance model was fit for the characters, namely, Days to first flower in crosses (H 1098-I x B 59- 1678), (H1117 x HS 6), (H1098-I x H 1117), seed index (cross H1098-I x H 1117), lint index in crosses (H1098-I x H 1117and B 59- 1678 x HS 6) and seed cotton yield in crosses (H 1098-I x B 59- 1678, H1098-I x H 1117 and B 59- 1678 x HS 6).All the three types (i, j and 1) or either of them of epistatic effects were significant for most of the cases wherein additive x additive (i) type of interaction was reported for plant height, boll number, boll weight, GOT, seed index and seed cotton yield.

These different biochemical parameters viz. tannin, phenol, gossypol provides defense mechanism to plants so have higher content in resistant and tolerant plants while susceptible have lower values. Also, sugar act as substrate for insects that's why susceptible plants have higher sugar content as compared to tolerant ones. However, there is no threshold level studied so far as it depends upon environmental conditions, genotypes, maturity stages and also varies from plant to plant.

REFERENCES

Abbas, A., Ali, M. A. and Khan, T. M. 2008. Studies on gene effects of seed cotton yield and its attributes in five American cotton cultivars. *J. Agri. Social Sci.* **4 :** 147-52

Acharya, V. S. and Singh, A. P. 2008. Biochemical basis of resistance in cotton to the whitefly, Bemisia tabaci Genn. *J. Cotton Res. Dev.* **22 :** 195-99.

Ahuja S.L. Monga D., Dhayal L.S. 2006. Genetics of resistance to cotton leaf curl disease in *Gossypium hirsutum* L. under field conditions. *J Hered* **49 :** 1-5

Ajmera, B.D. 1994. Occurrence of leaf curl virus on American Cotton (*G. hirsutum*) in north Rajasthan.Paper presentation, National Seminar on *"Cotton Production Challenges in 21st Century"*, April 18-20 Hisar. India.

Ali, M.A.; Abbas, A.; Younas, M.; Khan, T. M. and Hassan, H. M. 2009. Genetic basis of some quantitative traits in upland cotton (*Gossypium hirsutum L*). *Plant Omics Journal* **2 :** 91-97.

Anonymous 1998. *"Annual Report"* All India Co-ordinated cotton Improvement Project for the year (1997-1998). Pathology report. Coimbatore.

Azhar, M.T., Rehman, M.U., Aftab, S., Zafar, Y., Mansoor, S. 2010. Utilization of natural and genetically-engineered sources in *Gossypium hirsutum* for the development of tolerance against cotton leaf curl disease and fiber characteristics. *Int J Agric Biol* **12 :** 744-48

Beniwal, J.; Sharma, J.; Kumar, A.; Talwar, T. 2006. Assessment of losses due to leaf curl virus (CLCuV) disease in cotton (*Gossypium hirsutum*). *J. Cotton Res. Dev.* **20 :** 273- 79

Borkar, S. G. and Verma, J. P., 1991. Dynamics of phenols and diphenoloxidase contents of cotton cultivars during hypersensitive and susceptible reaction induced by *Xanthomonas campestris* pv. *malvacearum. Ind. Phytopath.*, **44 :** 280-90.

Cavalli, L.L. 1952. An analysis of linkage of quantitative inheritance. In: *Quantitative inheritance (E.C.R. Reeve and C.H. Weddington eds.), HMSC, London.* pp: 135-144.

Chakrabarthy, P. K., Mukewar, P. M., Sheo Raj and Sravankumar, V. 2002. Biochemical factors governing resistance in diploid cotton against Grey mildew. *Ind. Phytopath.*, **55** : 140-46.

Dasgupta, M. K. 1988. Principles of Plant Pathology, Published by Allied publishers private limited, pp 470-500

Dinham, B. 1993. The pesticide hazard, Zed books, London.224pp

Govindappa, N., Hosagoudar, J. And Chattannavar S. N. 2008. Biochemical studies in *Bt* and non *Bt* cotton genotypes against *Xanthomonas axonopodis* pv. *malvacearum. J. Cotton Res. Dev.* **22 :** 215-20

Hayman, B.I. 1958. The separation of epistasis from additive and dominance variation in generation. *Heredity*, **12**: 371-90.

Hayman, B.I. and Mather, K. 1955. The description of genetic interaction in continuous variation. *Biometrics,* **11** : 69-82.

Iqbal, M., Naeem M., Rizwan M., Nazer W., Shahid M Q., Aziz U., Aslam T and Ijaz M 2013. Studies of genetic variation for tield related traits in Upland Cotton. *American – Eurasian J. Agric Environ. Sci.,* **13 :** 611–18.

Jinks, J.L. and Jones, R. M. 1958. Estimation of components of heterosis. *Genet.,* **43 :** 223-34.

Kaushik, S.K. and Kapoor, C.J. 2006. Genetic variability and association study for yield and its component traits in upland cotton (*Gossypium hirsutum* L.). *J. Cotton. Res. Dev.,* **20 :** 185-90

Kliment, Y. and Goodman, R.N. 1967. The hypersensitive reaction to infection of bacterial plant pathogens. *Ann. Rev. Phytopath.* **5** : 17-44

Lu, H., Myers, G.O. 2011. Combining abilities and inheritance of yield components in influential upland cotton varieties. *Australian Jour. Crop Sci.,* **5:** 384-90.

Mather, K. 1967. Complementary and duplicate gene interactions in biometrical genetics. *Heredity*, **22**: 97-103.

Meyer,L., McDonald,S, and Kiawu,J. 2013. United States Department of Agriculture, Economic Research Service Situation Outlook; Cotton and WoolOutlook /CWS -13e/ May 14, 2013.

Rehman M, Hussain D, Malik TA Zafar Y 2005. Genetics of resistance to cotton leaf curl disease in *Gossypium hirsutum* L. Pl Pathol **54 :** 764-72.

Rishi, N. and Chauhan, M.S. 1994. Appearance of leaf curl disease of Cotton in northern India. *J. Cotton Res. Dev.* **8 :** 174-80.

Singh, J., Sohi, A.S., Mann, H.S. and Kapoor, S.P. 1994. Studies on whitefly *Bemisia tabaci* (Genn.) transmitted cotton leaf curl virus disease in Punjab. *J. Insect Sci.* **7 :** 194-98.

Swain, T. 1979. Phenolics in the environment. *Recent Advances in phytochemistry.***12 :** 624-37.

Varma, A., Puri, S.N., Raj, S., Bhardwaj. R.P., Kannan, A., Jayaswal, A.P., Srivastava, M. and Singh, J. 1995. Leaf curl disease of cotton in North-West-India. Report of the ICAR Committee, September, 1995.

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Study of molecular variability of *Alternaria* spp on *Bt* cotton

G. N. HOSAGOUDAR AND S. N. CHATTANNAVAR

Agricultural and Horticultural Reasearch Station, Ponnampet

E-mail : gnhosagoudar@rediffmail.com

ABSTRACT: RAPD analysis of *Alternaria* spp on *Bt* cotton revealed that the maximum genetic similarity of 93 per cent was between Gabbur (A_7) and Sunkeshwarhal (A_8) isolates, whereas the least similarity (40 per cent) was observed between Hattigudoor (A_9) and Yaragatti (A_{13}) isolates. The data was differentiated the isolates of *Alternaria* spp. into two major clusters *i.e.*, A cluster and B cluster. Cluster A was further sub-grouped in to 2 sub-clusters *viz.*, A1 encompassing Bijapur (A_{11}) isolate and A2 encompassing Yaragatti (A_{13}) and Bagalkot (A_{16}) isolates. Cluster B was further sub grouped in to 2 sub-clusters *viz.*, B1 and B2. The sub cluster B1 comprised of Kannolli (A_{11}) isolate. The sub cluster B2 comprised of the remaining isolates *i.e.* Dediapada (A_{17}), Ulligeri (A_{14}), Hattigudoor (A_9), Hanumanamatti (A_{12}), Kalmala (A_6), Javalgeri (A_5), Dharwad (A_4), Dharwad Farm (A_3), Annigeri (A_2), Sunkeshwarhal (A_8), Gabbur (A_7), Hirebagevadi (A_{15}) and UAS Dharwad (A_1) isolates. In B2 sub cluster maximum similarity was found between Gabbur (A_7) and Sunkeshwarhal (A_8) isolates as well as Annigeri (A_2) and Dharwad Farm (A_3) isolates. From the results it was clear that, all the isolates belonging to one geographical location have come in the same cluster, reflecting the fact that the variation is dependent on geographical locations. The PCR amplification and sequencing of ITS rDNA region of fungus was best molecular tool for identification of *Alternaria* spp. This is the first time of a sequence of *Alternaria dianthi* and two *Alternaria* spp. isolated from *Bt* cotton are to be publishing in this national symposium.

Key words: *Alternaria* spp, *Bt* cotton, Isolates, molecular variability

Cotton is one of the most ancient and important commercial crops next only to food grains and is the principal raw material for a flourishing textile industry. Currently, *Gossypium* includes 50 species, four of which are cultivated, forty four are wild diploids, and two are wild tetraploids (Percival and Kohel, 1990). Out of the four cultivated species, *Gossypium hirsutum* L. and *Gossypium barbadense* L. commonly called as new world cottons are tetraploids (2n = 4x = 52). Whereas, *G. herbaceum* L. and *G. arboreum* L. are diploids (2n = 2x = 26) and are commonly called as old world cottons.

There has also been a manifold improvement in production, productivity and quality with virtual increase in area. India now produces around 371.20 lakh bales of cotton ranging from short staple to extra long staple from an area of 121.91 lakh ha with productivity of 481.23 kg/ha (Anonymus, 2012). In Karnataka, the area under cotton cultivation is 5.49 lakh ha with a production of 13.10 lakh bales and an average productivity of 405.65 kg/ha (Anonymus, 2012).

With the introduction of *Bt* cotton hybrids possessing resistance to American boll worm the area has been increasing and several reports are being added on the outbreak of various diseases on *Bt* cotton. The first *Bt* cotton hybrid was released by Monsanto-Mahyco Biotech during 2002. In Madhya Pradesh, the crop was afflected by the leaf curl virus (LCV), with 100 per cent infection. It is an irony that while some of the private hybrids and varieties released earlier were resistant to LCV, but *Bt* cotton was found to be susceptible to LCV. Simultaneously, in the Vidarbha belt of Maharashtra, cotton crop planted over 30,000 ha has been widely affected because of the emergence of a disease of the roots called 'root rot'. It is believed that this disease is caused due to a mismatch of the *Bt* genes relevant in the USA and India. Many farmers have recorded only up to 50 per cent germination of seeds and many others had poor germination (Ranja Sengupta, 2002).

However, the production potential of the crop has not been fully exploited due to several biotic and abiotic factors. The crop suffers from many fungal diseases, of which foliar diseases take a heavy toll and among the diseases, *Alternaria* leaf spot causes yield losses up to 26 per cent (Chattannavar *et al.*, 2006). Even before the cultivation of *Bt* cotton, *Alternaria* leaf spot of cotton was one of the most important diseases noticed throughout the world.

There is a need to understand different aspects of *Alternaria* spp with respect to its genetic variability since not much work has been done on these aspects in the past. In addition, it helps in comprehensive understanding of causal the organism. Keeping this in view, the present investigations were under taken to study the molecular variability of *Alternaria* leaf spot of *Bt* cotton caused by *Alternaria* spp

MATERIALS AND METHODS

Molecular variability among the isolates of *Alternaria* spp on *Bt* cotton : Total genomic DNA from fungal isolates was extracted by using the CTAB DNA extraction protocol for plant DNA isolation from Saghai-Maroof *et al* (1984). The isolated DNA was then purified by Proteinase K and RNase A treatments for one hour. each, at 37 ^{0}C followed by one extraction with a 1:1 mixture of phenol: chloroform + isomyl alcohol (24:1 v/v) and two chloroform + isomyl alcohol (24:1 v/v) extractions. The DNA in the final aqueous layer was then precipitated by adding 1/10 times volume of 3M sodium acetate, pH 5.6 and two times with 70% ethanol, dried under vacuum and dissolved in minimum volume of 10:1 tris-EDTA, pH 8.0 buffer. The DNA concentration was estimated with a DNA fluorometer (Hoeffer Scientific, San Francisco, USA) using Hoechst 33285 as the DNA intercalating dye and calf thymus DNA as the standard (Brunk *et al.*, 1979). These estimates were confirmed by staining DNA with ethidium bromide after electrophoresis in 0.8 per cent agarose gel at 100 V for 1 hr. in Tris-acetate-EDTA (TAE) buffer (0.4 M Tris-acetate, 0.001 M EDTA, pH 8.0) using known DNA concentration standards (ë DNA, uncut).

PCR optimization and primer survey : The reaction condition for polymerase chain reaction (PCR) was optimized by varying concentrations of template DNA (10-60 ng), AmpliTaq DNA polymerase (0.5-2U) and Mg $^{++}$ salt (0-5 mm) in order to identify the most suitable RAPD primers for the study of molecular variations among the isolates. Thirteen random decamer primers from the OPA-02, OPA-03, OPA-07, OPC-05, OPC-06, OPC-15, OPD-07, OPM05, OPM-10, OPM-20, OPO-02, OPO-10 and OPO-16 (all primers from M/s Bangalore Genei, Pvt. Ltd. Bangalore) were surveyed and the primers generating highly polymorphic amplification products were identified and used for analyzing all the isolates.

PCR and agarose gel electrophoresis : PCR reactions were carried out in a DNA Thermal Cycler (Eppendorf, Master cycler gradient) each of the 25 µl reaction mixture contained 1X reaction buffer (10 mM Tris-Cl, pH 8.3 and 50

Random primers with following sequences were used in RAPD

Sl. No.	Primer	Sequence
1	OPA-02	TGCCGAGCTG
2	OPA-03	AGTCAGCCAC
3	OPA-07	GAAACGGGTG
4	OPC-05	GATGACCGCC
5	OPC-06	GAACGGACTC
6	OPC-15	GACGGATCAG
7	OPD-07	TTGGCACGGG
8	OPM-05	GGGAACGTGT
9	OPM-10	TCTGGCGCAC
10	OPM-20	AGGTCTTGGG
11	OPO-02	ACGTAGCGTC
12	OPO-10	TCAGAGCGCC
13	OPO-16	TCGGCGGTTC

mM KCl), 3 mM $MgCl_{2,}$ 1 U of Taq DNA polymerase; 200 µM each of dATP, dTTP, dCTP and dGTP (all reagents from M/S Bangalore Genei, Pvt. Ltd. Bangalore); 0.6 µM of primer and approximately 20 ng of template DNA. The PCR amplification conditions were as follows: Initial extended step of denaturation at 94 ^{0}C for 3 min followed by 40 cycles of denaturation at 94 ^{0}C for 1 min, primer annealing at 32 ^{0}C for 1 min and primer elongation at 72 ^{0}C for 1 min, followed by an extended elongation of step at 72^{0}C for 5 minutes. Reaction products were mixed with 2.5 µml of 10X loading dye (0.25% bromophenol blue, 0.25% Xylene Cyanol and 40% Sucrose, w/v) and spun briefly in a microfuge before loading on the gel (Sambrook *et al.*, 1989). The amplification products were electrophoresed on 1.2 per cent agarose gel at 100 volts. Gels were stained with ethidium bromide and photographed on poloroid 667 film under ultra violet light.

Scoring of amplified fragments : The amplified profiles for all the primers were compared with each other and bands of DNA fragment were scored as 'l' for presence and '0' for absence, generating '0' and '1' matrix. Per

Table 1. Banding profile of different primers for different isolates of *Alternaria* spp

Sl. No.	Primer	Total bands	Polymorphic bands	Per cent polymorphism
1	OPA-02	6	3	50.00
2	OPA-03	7	7	100.00
3	OPA-07	5	5	100.00
4	OPC-05	5	5	100.00
5	OPC-06	6	6	100.00
6	OPC-15	7	6	85.71
7	OPD-07	3	2	66.66
8	OPM-05	8	8	100.00
9	OPM-10	9	9	100.00
10	OPM-20	6	6	100.00
11	OPO-02	6	6	100.00
12	OPO-10	7	7	100.00
13	OPO-16	7	6	85.57

cent polymorphism was calculated by using the formula.

$$\text{Per cent polymorphism} = \frac{\text{Number of polymorphic bands}}{\text{Total number of bands}} ´ 100$$

Analysis of the profile of the amplified fragments : Pair wise genetic similarities between isolates were estimated by DICE similarity coefficient. Clustering was done using the symmetric matrix of similarity coefficient and cluster obtained based on un weighted pair group arithmetic mean (UPGMA) using sequential agglomerative hierarchal nested (SAHN) cluster analysis of NTSYS-PC version 2.0 (Rohlf, 1998).

Internal Transcribed Spacer (ITS) – Polymerase Chain Reaction (PCR) : The ribosomal DNA (rDNA) unit contains genetic and non-genetic or spacer region. Each repeat unit consists of a copy of 18S, 5.8S and 28S like rDNA and its spacer like Internal Transcribed Spacer (ITS) and intergenic spacers (IGS). The rDNA

Table 2. Similarity co-efficient of seventeen isolates of Alternaria spp.

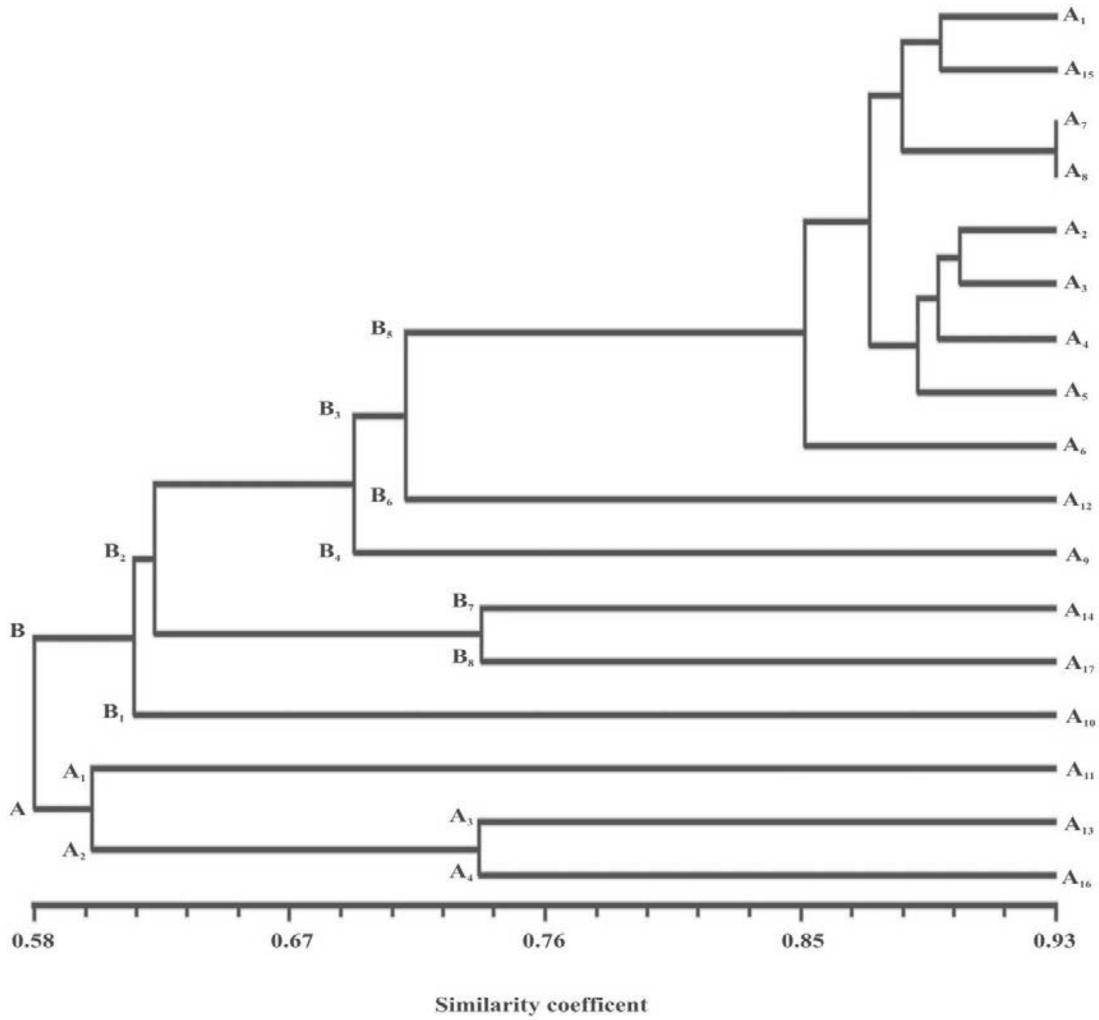
Isolates	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}
A_1	1.00																
A_2	0.87	1.00															
A_3	0.90	0.90	1.00														
A_4	0.84	0.89	0.90	1.00													
A_5	0.87	0.89	0.88	0.89	1.00												
A_6	0.84	0.88	0.84	0.81	0.88	1.00											
A_7	0.89	0.89	0.88	0.87	0.87	0.88	1.00										
A_8	0.84	0.89	0.85	0.86	0.89	0.85	0.93	1.00									
A_9	0.71	0.75	0.71	0.70	0.71	0.64	0.71	0.73	1.00								
A_{10}	0.59	0.65	0.59	0.64	0.62	0.58	0.62	0.61	0.65	1.00							
A_{11}	0.63	0.65	0.68	0.62	0.58	0.59	0.63	0.59	0.44	0.46	1.00						
A_{12}	0.68	0.74	0.73	0.73	0.68	0.64	0.73	0.75	0.54	0.59	0.60	1.00					
A_{13}	0.59	0.51	0.56	0.56	0.55	0.55	0.59	0.60	0.40	0.44	0.56	0.58	1.00				
A_{14}	0.68	0.74	0.70	0.67	0.68	0.66	0.73	0.69	0.65	0.68	0.52	0.63	0.42	1.00			
A_{15}	0.89	0.85	0.86	0.85	0.87	0.80	0.89	0.89	0.69	0.63	0.66	0.69	0.59	0.68	1.00		
A_{16}	0.75	0.69	0.71	0.68	0.71	0.71	0.71	0.70	0.48	0.48	0.65	0.63	0.73	0.55	0.75	1.00	
A_{17}	0.57	0.62	0.59	0.55	0.57	0.55	0.57	0.58	0.50	0.53	0.45	0.53	0.41	0.73	0.55	0.42	1.00

have been employed to analyze evolutionary events because it is highly conserved, where as ITS rDNA is more variable. Hence, it has been used for investigation of these species level relationships.

ITS-PCR amplification of rDNA sequences for *Alternaria* species was conducted in 50 ml reaction volumes using conserved ITS1 and ITS4 primers (White *et al*, 1990). Each reaction consisted of 2 ml of 50 ng/ml DNA template, 5 ml of 10X PCR buffer, 0.5 ml of 25mM dNTPs, 1.5 ml of 15 mM MgCl2, 0.3 ml of 1.25U Taq DNA polymerase, 1 ml each of 10 mM primers ITS1 (5' TCC GTA GGT GAA CCT GCG G 3') and ITS 4 (5' TCC TCC GCT TAT TGA TAT GC 3 ') and 38.7ml sterile distilled water. The PCR protocol was standardized to amplify rDNA sequences from a strain each of *Alternaria* spp. infecting cultivated species of *Bt* cotton. The standardized protocol had cycling parameters of initial denaturation at 94°C for 4 minutes followed by 33 cycles of denaturation at 94°C for 1 min, annealing at 55°C for 1 min and extension at 72°C for 1.5 min. A final extension at 72°C for 5 minutes was done at the end of amplification. Negative controls were used to test for false priming and amplification. A 10-ml PCR amplification product for each of the *Alternaria* species was visualized in a 1.2 per cent agarose gel and viewed under UV light following staining with ethidium bromide.

RESULTS AND DISCUSSION

Molecular variability among the isolates of *Alternaria* spp on *Bt* cotton : The analysis of genetic variation in plant pathogen populations is an important prerequisite for understanding the evolution in the plant-patho system. Polymerase chain reaction (PCR) based molecular markers are useful tools for detecting genetic variation within populations of plant pathogens. Random Amplified Polymorphic DNA (RAPD) was used to detect the variation among the 17 isolates of *Alternaria* spp collected from different districts of North Karnataka. OPA, OPC, OPD, OPM and OPO series of primers obtained from Operon technologies, M/S Bangalore Genie,



A_1: UAS Dharwad	A_2: Annigeri	A_3: Dharwad Farm	A_4: Dharwad
A_5: Javalgeri	A_6: Kalmala	A_7: Gabbur	A_8: Sunkeshwarhal
A_9: Hattigudoor	A_{10}: Kannolli	A_{11}: Bijapur	A_{12}: Hanumanamatti
A_{13}:Yaragatti	A_{14} :Ulligeri	A_{15}: Hirebagevadi	A_{16}: Bagalkot
A_{17}:Dediapada (GJ)			

Fig. 1a. Dendrogram based on RAPD analysis of 17 isolates of *Alternaria* spp.

were used to determine genetic diversity among the isolates to construct a dendrogram. The profile of amplicons of different primers for seventeen isolates of *Alternaria* spp. is given in Table 1 and Fig 1. Among the 13 primers used for amplification OPA-03, OPA-07, OPC-05, OPC-06, OPM-05, OPM-10, OPM-20, OPO-02 and OPO-10 showed cent per cent polymorphism. The isolates exhibited overall polymorphism of about 92.68%. Out of a total of 82 bands, 76 polymorphic bands were obtained. Out of 13 primers OPA-02, OPA-08, OPB-02 and OPF-06 showed 100 per cent polymorphism.

The banding profile per primer also varied from minimum of 3 bands (OPD 07) to maximum of 9 bands (OPM 10). From the RAPD analysis, the results revealed that a total of 92.68 per cent polymorphism was found between the isolates, indicating there is a molecular variability among the isolates. Information on the banding pattern for all the primers was used to determine genetic distance between the isolates and to construct a dendrogram by using unweighted pair group arithmetic mean method (UPGMA). Based on the simple matching coefficient a genetic similarity matrix was constructed to access the genetic relativeness among the isolates. The genetic similarity co efficient of seventeen isolates based on RAPD analysis is given in Table 2 and Fig. 1a.

The similarity co-efficient ranged from 0.40 to 0.93. The maximum genetic similarity of 93 per cent was between Gabbur (A_7) and Sunkeshwarhal (A_8) isolates. There was 90 per cent similarity between Annigeri (A_2) and Dharwad Farm (A_3) isolates, where as least similarity (40 per cent) was observed between Hattigudoor (A_9) and Yaragatti (A_{13}) followed by least similarity (41%) was observed between Yaragatti (A_{13}) and Dediapada (A_{17}). Further, the dendrogram constructed by UPGMA from the pooled data clearly showed two major clusters *viz.*, A and B at a similarity co-efficient of 0.58 (Fig. 1). Cluster A was further sub grouped in to 2 sub clusters *viz.*, A1 encompassing Bijapur (A_{11}) isolate and A2 encompassing Yaragatti (A_{13}) and Bagalkot (A_{16}) isolates. Cluster B was further sub grouped in to 2 sub clusters *viz.*, B1 encompassing Kannolli (A_{11}) isolate and B2 encompassing remaining all the isolates Dediapada (A_{17}), Ulligeri (A_{14}), Hattigudoor (A_9), Hanumanamatti (A_{12}), Kalmala (A_6), Javalgeri (A_5), Dharwad (A_4), Dharwad Farm (A_3), Annigeri (A_2), Sunkeshwarhal (A_8), Gabbur (A_7), Hirebagevadi (A_{15}) and UAS Dharwad (A_1) isolates. In B2 sub cluster maximum similarity was found between Gabbur (A_7) and Sunkeshwarhal (A_8) isolates as well as Annigeri (A_2) and Dharwad Farm (A_3) isolates.

Polymerase chain reaction (PCR) based molecular markers are useful tools for detecting genetic variation within populations of plant pathogens. Random amplified polymorphic DNA (RAPD) markers have been widely used for estimating genetic diversity in natural populations (Annamalai *et al.*, 1995). The analysis of RAPD polymorphism in isolates of *Alternaria* spp from different agro climatic regions across North Karnataka revealed the occurrence of high level of polymorphism (92.68%) indicating wide and diverse genetic base.

Amplification of ITS1 and ITS4 region : The full length ITS rDNA region was amplified with ITS1 (5' TCC GTA GGT GAA CCT GCG G 3 ') and ITS 4 (5' TCC TCC GCT TAT TGA TAT GC 3 ') primers for among 17 isolates of *Alternaria* spp. Only 4 isolates were sent for confirmation at species level after the identification from Agharkar Research Institute, Pune. DNA amplicon was observed at the region 575 bp with concentration of around 150 ng/mg. The amplified products were checked on 1.2% agarose gel electrophoresis (Fig 2).

This seems to be the first report of amplification of ITS rDNA region of *Alternaria dianthi* isolated from *Bt* cotton in india. Since, there is less number of ITS rDNA region of isolate (A_2) *Alternaria dianthi* in gene bank itself.

Sequences of *Alternaria* spp ITS rDNA

DNA sequencing : The DNA sequences were obtained for ITS rDNA. The sequences of these isolates are given below.

$_{A2}$isolate,ITS-1

GAAAGGCGGGATGGACGGGCTGGATCT
CTCGGGGTTACAGCCTTGCTGAATTAT
TCACCCTTGTCTTTTGCGTACTTCTTG
TTTCCTTGGTGGGTTCGCCCACCACTA
GGACAAACATAAACCTTTTGTAATTGCA
ATCAGCGTCAGTAACAAATTAATAATTA
CAACTTTCAACAACGGATCTCTTGGTTC
TGGCATCAATGAAGAACGCCTTTGAATG
CGAAAGGGCTGTGAATTGCAGAATTCT
TTGAATCTTCAAATCTTTCAACGATTCT
TGCGCCCTTTGGTATTTCAAAGGGTTC
GTCTGTTCTGCCGTAACTTAGACACCC
GATGTTTGAATGTGGTATTATTAATTTG
TTACTGACTTTGATTGCAATTACAAAAA
GTTTATGTTTGTCCCAGTGGTGGGCGA
ACCCACCAAGGAAACAAGAAGTACCCC
CAAAGACAAAGGTGAATAAATCCACAAG
GGTGTTTTTTCCCAGAGATTCCCCCCC
CCCCTCATAGTTGTGTAATGAACCCTC
CCCAAGTTCACATACGGGAAAA

$_{A2}$isolate,ITS-4

GCCGGTAGGCGAGAGGCTGGCATCTCT
CGGGTGTACAGCGGCTTAATGGAAGCT
ACACCTTTGCTGAGCGAGAGTGCGACT
TGTGCTGCGCTCCGAAACCAGTAGGCC
GGCTGCCAATTACTTTAAGGCGAGTCT
CCAGCAAAGCTAGAGACAAGACGCCCA
ACACCAATCAAAGCTTGAGGGTACAAAT
GACGCTCGAACAGGCATGCCCTTTGGA
ATACCAAAGGGCGCAATGTGCGTTCAA
AGATTCGATGATTCACTGAATTCTGCAA
TTCACACTACTTATCGCATTTCGCTGC
GTTCTTCATCGATGCCAGAACCAAGAG
ATCCGTTGTTGAAAGTTGTAATTATTAA
TTTGTTACTGACGCTGATTGCAATTACA
AAAGGTTTATGTTTGTCCTAGTGGTGGG
CGAACCCACCAAGGAAACAAGAAGTAC
GCAAAAGACAAGGGTGAATAATTCCGC
AAGGCTGTTTCCCCCAGAGATTCCACC
CCGCCTTCATATTTGTGTAATGATCCC
TCCCCAAGTTCACCTACGAGAAAAA

$_{A5}$isolate,ITS's-1

AGCGGAAGGCGGGCTGGATCTCTCGGG
GTTACAGCCTTGCTGATTATTCACCCT
TGTCTTTTGCGTACTTCTTGTTTCCTTG
GTGGGTTCGCCCACCACTAGAGAAGCA
AAATACTTTTGTAATTGCAATCAGCGTC
CTAGAGAATTACAAATTACACCTTTCAA
CGCCTGATGGTATGGGGAGGGTTCGAT
GAAGAAGGCCTCGGAAAGGGAAAAGGC
GGCGAAGTGGGTTCTTTAAGGAAGGAT
TATTCATTGAAGCATTAACCGCCCTTTG
CGATTTCAGTTCCTTCGGTCATCAAAG
CGAGAACCAAAAAATCCATTCTGAAATT
GGTGTTGGTTAATTTGTCACTGACGCT
GATGGAAATTACCAAAGGTTTATTTGTG
TCCCGGTGGAGGGCGAACCGACCAACG
CAACATTAAAACCCCTAAAAACAAGGGT
AAAAAATCCACAAGGGCGGGAGCCGGA
AGAAGATCCCGCATCCGGTAAGATTAG
CGGCGGACCCCACGATAAGACACAGCG
GAGGAAAG

$_{A5}$isolate,ITS-4

ACGTAATGGGTAAAGTGAAAAATTAGGA
GGGCTCGGAGTCTCAGGTTTCAACCGC
TGCTTGGATGCTACACCTTTGCTGAGG
AGAGTGCGACTTGTGCTGCGCTCCGAA
ACCAGTAGGCCGGCTGCCAATTACTTT
AAGGCGAGTCTCCAGCAAAGCTAGAGA
CAATACACCCAACACCTTTCAAAGCTTG
AGGGTACAAATGACGCTCGAACAGGCA
TGCCCTTTGGAATACCAAAGGGCGGGT
GGTGCGTTAATCTTCGATGATTCAATGA
ATTCAACAAATCATACCACCTTTTGTAT
TTCCGTGCGTTTTTCCTTGAAGGCCGA
ACCCAGAAAATCCGTTGTTGAATTTTGT

ATTGATCATTTTGTAACGGACTTTGATG
GAAATTCCAAAAGGTTTATTTGGGCCCA
GGTGGTGGGGTAACCCACCCAATTTTT
TTTAACAATCCAAAAAAGCAAGGGTAAA
AAATCCATAAAGCTTTTTATCCAACTTT
ATATCCCCCCCCCCACGTAAGTTTCCG
AAAGAACCTTACGCATATGTTTAAACGG
GAGAAAACG

$_{A8}$isolate,ITS's-1

CAGCGGAAGCCGGGCTGGAATCTCTCG
GGGTTACAGCCTTGCTGAATTATTCAC
CCTTGTCTTTTGCGTACTTCTTGTTTCC
TTGGTGGGTTCGCCCACCACTAGGACA
AACATAAACCTTTTGTAATTGCAATCAG
CGTCAGTAACAAATTAATAATTACAACT
TTCAACAACGGATCTCTTGGTTCTGGC
ATCGATGAAGAACGCAGCGAAATGCGA
TAAGTAGTGTGAATTGCAGAATTCTGTG
AATCTTCGAATCTTTGAACGCACATTGC
GCCCTTTGGTATTCCAAAGGGCATGCC
TGTTCGAGCGTAATTTGTACCCTCAAG
CTTTGATTGGGGTTGGGCGTCTTGGCT
CTAGCTTTGCTGGAGACTTACCTTAAAG
TAATTGGCAGCCGGCCTACTGGTTTCG
GAGCGCAGGAAACAGTCGCACTCTCTA
AGAGCAAAGGTCTAGCATCCATTAAGC
CTTTTTTCAACTTTTGACCTCGCGCTC
CTTTATATATACCCGCTGAACCTACCC
ATATTTCTAATCCGAGAAAAAA

$_{A8}$isolate,ITS-4

ACAAGCGGGAATGGAGGGCTGGGTCTC
TCGGGTGTACAGCGGCTTAATGGAAGC
TACACCTTTGCTGAGCGAGAGTGCGAC
TTGTGCTGCGCTCCGAAACCAGTAGGC
CGGCTGCCAATTACTTTAAGGCGAGTC
TCCAGCAAAGCTAGAGACAAGACGCCC
AACACCTTTCAAAGCTTGAGGGTACAAA
TGACGCTCGAACAGGCATGCCCTTTGA
AATACCAAAGGGCGCAATGTGCGTTCA
AAGATTCGATGATTCACTGAATTCTGCA
ATTCACGCTACTTATCGCATTTCGCTG
CGTTCTTCAGCGATGCCAGAACCAAGA
CATCCGTTGTTGAAAGTTGTAATTATTA
ATTTGTTACTGACGCTGATTGCAATTAC
AAAAGGTTTATGTTTGTCCTAGTGGTGG
GCGAACCCACCAAGGAAACAAGAAGTA
CGCAAAAGACAAGGGTGAATAATTCAGC
AAGGCTGTTTCCCCGAGAGATTCCAGC
CCGCCTTCATATTTGTGTAATGATCCC
TCCGCAAGTTCACCTACGGAAAA

$_{A15}$isolate,ITS's-1

ACGGGGAGCAGGGCTGGATCTCTCGGG
GTTACAGCCTTGCTGAATTATTCACCC
TTGTCTTTTGCGTACTTCTTGTTTCCTT
GGTGGGTTCGCCCACCACTAGGACAAA
CATAAACCTTTTGTAATTGCAATCAGCG
TCAGTAACAAATTAATAATTACAACTTT
CAACAACGGATCTCTTGGTTCTGGCAT
CGATGAAGAACGCAGCGAAATGCGATA
AGTAGTGTGAATTGCAGAATTCAGTGAA
TCATCGAATCTTTGAACGCACATTGCG
CCCTTTGGTATTCCAAAGGGCATGCCT
GTTCGAGCGTCATTTGTACCCTCAAGC
TTTGCTTGGTGTTGGGCGTCTTGTCTC
TAGCTTTGCTGGAGACTCGCCTTAAAG
TAATTGGCAGCCGGCCTACTGGTTTCG
GAGCGCAGCACAAGTCGCACTCTCTAT
CAACAAAGGTCTAGCATCCATTAAGGC
CTTTTTTCAACTTTTGACCTCGGATCAG
GTAGGGATACCCGCTGAACTTAACCAT
ATCAATAAGCGGAAAAAAAAA

$_{A15}$isolate,ITS-4

GTAGCCGGTCGGCAGAGCTGGAATCTC
TCGGGTGTACAGCGGCTTAATGGATGC
TAGACCTTTGCTGATAGAGAGTGCGAC
TTGTGCTGCGCTCCGAAACCAGTAGGC

CGGCTGCCAATTACTTTAAGGCGAGTC
TCCAGCAAAGCTAGAGACAAGACGCCC
AACACCAAGCAAAGCTTGAGGGTACAA
ATGACGCTCGAACAGGCATGCCCTTTG
GAATACCAAAGGGCGCAATGTGCGTTC
AAAGATTCGATGATTCACTGAATTCTGC
AATTCACACTACTTATCGCATTTCGCTG
CGTTCTTCATCGATGCCAGAACCAAGA
GATCCGTTGTTGAAAGTTGTAATTATTA
ATTTGTTACTGACGCTGATTGCAATTAC
AAAAGGTTTATGTTTGTCCTAGTGGTGG
GCGAACCCACCAAGGAAACAAGAAGTA
CGCAAAAGACAAGGGTGAATAATTCAGC
AAGGCTGTAACCCCGAGAGATTCCAGC
CCGCCTTCATATTTGTGTAATGATCCC
TCCCCAAGTTAACCTACGAAAAAAA

The DNA sequences of selected isolates were compared using bioinformatics tools like National Centre for Bioinformatics (NCBI) blast programme. Based on sequence comparison, the identification of *Alternaria* spp. isolates confirmed and all the ITS rDNA sequences of isolates were confirmed as one *Alternaria dianthi,* two *Alternaria* spp. and one *Alternaria alternata.* The list of isolates, Accession number, Maximum per cent homology and name identified are given in a Table 3.

These results are in conformity with the reports of Kadam (2005) who studied that the amplified products of ITS region of 11 fungal species from different crops, including strains of *R. solani, R. bataticola, A. macrospora* and *R. areola* reported in the present study, ranged between 569-575 bp, coinciding with the sizes obtained from similar fungal pathogens from other strains of the same species. Molecular techniques, if not alone, can be used in conjunction with classical methods where the latter approaches can at least narrow pathogen diagnosis to genus level. Once genus is narrowed by morphology, symptomatology, host-specificity, *etc*., then PCR can be used to differentiate species (Chakrabarty *et al.* 2007).

Table 3. Comparison and identity of *Alternaria* spp of *Bt* cotton with referred gene bank

Isolates No.	ITS, Primers	Agarkhar Research Institute, Pune identified as	Gene Bank Accession number	Strains	Reference	Maximum (%) Homology with
A_2	ITS1	*Alternaria dianthi*	D38758	DA-1	Kusaba and Tsuge (1995)	95(%) with *A. dianthi*
	ITS4		AY154702	IA259	Ghosta (2002)	95(%) with *A. dianthi*
A_5	ITS1	*Alternaria* spp	FJ899921	MDF1.1	Shweta *et al.* (2009)	95(%) with *A. alternata*
	ITS4		AF397044	39/355	Konstantinova *et al.* (2009)	95(%) with *A. alternata*
A_8	ITS1	*Alternaria* spp	HM003680	SVJM015	Visalakchi *et al.* (2010)	95(%) with *A. alternata*
	ITS4		DQ156341	S	Chakrabarty *et al.* (2005)	95(%) with *A. alternata*
A_{15}	ITS1	*Alternaria alternata*	DQ156341	S	Chakrabarty *et al.* (2005)	95(%) with *A. alternata*
	ITS4		DQ156341	S	Chakrabarty *et al.* (2005)	95(%) with *A. alternata*

REFFERENCES

Annamalai P., Ishii H., Lalithakumari, D. and Revathi, R., 1995. Polymerase chain reaction and its application in fungal disease diagnosis. *J. Pl. Dis. Prot.* **102**: 91-104.

Anonymous, 2012. *Ann. Rep.* of All India Co-ordinated Cotton Improvement Project, for *2011-12*, Central Institute for Cotton Research Regional Station, Coimbatore.

Brunk C F, Jones K C and James T W., 1979. Assay for nanogram quantities of DNA in cellular homogenates. *Anals of Bioch.* **92** : 497-500.

Chakrabarty, P. K., Chavhan, R. L., Sable, S. V., Narwade, A. V., Monga, D. and Khadi, B. M., 2007. Development of sensitive molecular diagnostic tools for detection of economically important fungal pathogens of cotton. Invited paper presented *"In: World cotton reasearch conference-4".*

Chakrabarty P K, Kadam B P, Chavhan R L and Mayee C D., 2005. rRNA gene sequence of *Alternaria alternata* strain S1 isolated from sorghum seeds. Submitted Crop Protection Division, Central Institute for Cotton Research, Nagpur, India.

Chattannavar, S. N., Srikant Kulkarni and Khadi, B. M., 2006. Chemical control of *Alternaria* blight of cotton *J. Cotton Res. Dev.,* **20** : 125-26.

Ghosta, Y., 2002. Direct Submission, Plant Protection, Oromyieh University, Oromyieh, West Azarbayejan, Iran.

Kadam, B. P., 2005. Characterization of molecular variability among some species of Alternaria that cause economically important diseases of crop plants and development of molecular diagnostic tools. P. 57 + II. *M. Sc. Thesis,* M. A. U., Parbhani.

Konstantinova, P., Bonants, P. J. M. and Vanden Bulk, R., 2001. Development of specific primers for the detection and identification of *Alternaria* spp. in carrot material by PCR and comparison with blotter and plating assays, Submitted Biointeractions and Plant Health, Plant Research International, Wageningen, Netherlands.

Kusaba M., and Tsuge, T., 1995. Phylogeny of *Alternaria* fungi known to produce host-specific toxins on the basis of variation in internal transcribed spacers of ribosomal DNA, *Cur. Gen.* **28** : 491-98.

Percival, E. and Kohel, R. J., 1990. Distribution, collection and evaluation of *Gossypium. Advan. Agron.* **44** : 225-28.

Ranja Sengupta., 2002. Failure of *Bt* cotton in India. *www. biotech.info.net.*

Rohlf, F. I., 1998. NTSYS – PC Numerical taxonomy and multivariate analysis version 2. 0 *Applied Biostatistics Inc.*, New York.

Saghai-Maroof, M. A., Soliman, K. M., Jorgesen, R. A. and Allard, R. W., 1984. Ribosomal DNA spacer-length polymorphisms in barley mendelian inheritance, chromosomal location and population dynamics. *Proc. Nat. Acad. Scie., USA.*, **81** : 8014-18.

Shweta, S., Ramesha, B. T., Priti, V., Ravikanth, G., Ganeshaiah, K. N. and Uma Shanker, R., 2009. Novel endophytic fungus from Icacinaceae, Direct Submission Department of Crop Physiology, Univ. of Agric. Scie., GKVK, Bangalore, Karnataka (India).

0Visalakchi, S., Srinivasan, K. and Muthumary, J., 2010. Screening of taxol producing endophytic fungus from medicinal plant, *Indigofera enneaphylla* L. Submitted CAS in Botany, Univ. of Madras, Chennai, Tamilnadu, India

Jasmonic acid and salicylic acid induced protection against cotton leaf curl disease

RITU RAJ, P. S. SEKHON, M K SANGHA AND DHARMINDER PATHAK

Department of Plant Pathology, Punjab Agricultural University, Ludhiana 141004

E-mail: rituraj1610@gmail.com

ABSTRACT : The present study highlights the effectiveness of Jasmonic acid (JA) and Salicylic acid (SA) spray against CLCuD. Response of different American cotton accessions namely RS 921, LH 2076, PIL 8, Ankur 3028 BGII and a *desi* cotton variety LD 694 to JA and SA in the induction of proteins for protection against cotton leaf curl disease (CLCuD) was studied. At four to six leaf stage, potted plants of different cotton accessions were sprayed with different concentration of JA and SA *i.e* 50 µM, 100 µM, 150 µM and 200 µM. JA at 150 µM and SA at 200 µM caused maximum protein induction in all the treated cultivars *w.r.t* their control. JA was found to be more effective than SA in the induction of proteins. SDS-PAGE revealed induction of proteins in 15-45 kDa molecular weight range in treated samples as compared to their respective controls. JA @ 150 µM and SA @ 200 µM resulted in lower disease incidence as well as disease index. Disease incidence was recorded to be 37%, 30%, 30% and disease index was found to be 48%, 40%, 40% in RS 921, LH 2076, Ankur 3028 BGII at 150 µM concentration of JA whereas, at 200 ìM SA disease incidence of 48%, 36%, 34% and disease index of 57%, 50%, 50% was recorded in above mentioned accessions respectively. The respective controls exhibited higher values for disease incidence and disease severity. Latent carry over detection of symptomless plants treated with 150 µM of JA and 200 µM of SA through PCR amplification using DNA â specific primers confirmed the presence of virus in all the tested cotton accessions except LD 694 which depicted that induced proteins do not eliminate virus but might be playing a role in suppressing the proliferation of virus or might have kept virus in inactive state. JA and SA application thus, resulted in imparting tolerance with the induction of PR proteins but does not lead to complete resistance against the disease.

Key words: Cotton leaf curl disease, jasmonic acid, latent carry over, proteins, salicylic acid

Plants are constantly attacked by various types of pathogen as a result they have evolved a plethora of wide variety of defence mechanisms which can be either local, systemic, constitutive or inducible. One particular inducible systemic response, is Systemic Acquired Resistance (SAR). SAR refers to a distinct signal transduction pathway that plays an important role in the ability of plants to defend themselves against pathogens by the induction of various types of proteins and metabolites. Application of novel plant protection chemicals that act by stimulating the plant's inherent disease resistance mechanisms by means of induction of various types of proteins thus could prove beneficial in disease management. It is found that certain natural and synthetic compounds e.g. Jasmonic acid (JA), Salicylic acid (SA) and their structural analogues are capable of activating the defense mechanisms in plant and prove helpful in conferring tolerance/resistance against various pathogens (Wang *et al.,* 2005). Vanwees (2000) in his work signified the importance of SAR inducers like salicylates and jasmonates against broad spectrum of pathogens. Moreover, chemical inducers of plant resistance possess quite different mode of action as compared to fungicides. The latter products have direct toxic effect on pathogens; are noxious to environment; have narrow spectrum of defense; ensure short lasting protection (Kuc 2001). Thus, application of chemical inducers of resistance is an exciting new perspective to supplement the classical chemical means of disease control by providing both effective and ecologically-friendly plant protection. Present investigations were carried out to study the role of Jasmonic acid and Salicylic acid for the induction of resistance to cotton leaf curl disease CLCuD in cotton.

MATERIALS AND METHODS

Materials and treatment : Seeds of three Gossypium hirsutum accessions namely RS 921 (highly susceptible), LH 2076 (moderately resistant), PIL 8 (resistant) and one G. arboreum LD 694 (immune) possessing differential resistance to CLCuD used in this study were procured from Cotton Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. A G. hirsutum hybrid Ankur 3028 BGII was provided by Ankur Seeds Pvt. Ltd. Twelve seeds of each cotton accession were sown in earthen pots in duplicate and kept in insect proof screen cages under natural conditions.

Treatment of seedlings with JA and SA : JA and SA @ 50 μM, 100 μM, 150 μM and 200 μM were applied as foliar spray with atomizer at 4-6 leaf stage of plants. Water sprayed plants served as controls.

Sample collection : For protein extraction, leaf samples were collected at 24, 48, 72, 96 hrs and a week interval of spray. Samples were brought to laboratory under refrigerated conditions and were stored at -80°C in deep freezer till further use.

Leaf tissue (0.2 g) was homogenized in 25 mM Tris HCl buffer (pH 8.0) in a pre-cooled pestle and mortar on ice. Homogenate was centrifuged at 10,000 rpm for 25 minutes at 40C. The supernatant was used as protein extract. Soluble proteins in supernatant were estimated by the method of Lowry et al., (1951) and expressed as mg/g fresh weight of tissues (mg/g fr. wt.).

Protein profiling using SDS-PAGE : Supernatant of different cotton accessions was subjected to SDS-PAGE (Walker 1996) for protein profiling. Protein samples were mixed with sample buffer (0.5 M Tris HCl, pH 6.8, 10 % SDS, Glycerol, 0.1% Bromophenol blue and 5% 2-Mercaptoethanol) in 1:1 ratio and kept in boiling water for 2 minutes and centrifuged. Supernatant (20 il) was taken and loaded in PAGE along with molecular marker (6-8kDa) and was run along with the samples. The Coomassie brilliant blue G 250 stained gel after destaining was preserved in 7 per cent acetic acid solution. The protein banding pattern of treated samples was analyzed.

Statistical analysis : Statistical analysis of the experimental data was done to test the significance of treatments using factorial completely randomized design. Critical differences were tested at 5 per cent level of significance.

Inoculation and disease assessment : A week after spraying with JA and SA, plants were exposed to viruliferous whiteflies. The colonies of viruliferous whiteflies, were reared and maintained on highly susceptible potted cotton plants in separate screen house. Six whiteflies/plant were released for inoculation of CLCuV. CLCuD incidence and severity was calculated using the following formulae (Anonymous 2008):

$$\textbf{Disease Incidence (\%)} = \frac{Pi}{Pt} \times 100$$

Where,

Pi = Number of infected plants

Pt = Total number of plants

Disease index (%)

The plants were graded according to revised CLCuD scale described in AICCIP as given in Table 1(a) and (b)

$$\textbf{Disease index (\%)} = \frac{N1}{S1} \times \frac{S2}{N2} \times 100$$

Where,

N1= Number of plants in check

N2= Number of plants in test entry

S1= Sum of all infection grades in check

S2= Sum of all infection grades in test entry

Detection for the presence/absence of viral DNA in symptomless plants : Leaf samples from symptomless plants of different cotton accessions which were earlier treated with 150 ìM of JA and 200 ìM of SA and inoculated with viruliferous whiteflies were collected to detect the presence/absence of satellite DNA â through PCR amplification using DNA â specific primer pair. Total genomic DNA from symptomless cotton plants was isolated using the CTAB (Cetyl trimethyl ammonium bromide) method as reported by Shaghai-Maroof *et al.,* (1984). The primer pair used for cloning and sequencing of DNA â (Anup 2013) were used for *in vitro* PCR based amplification/identification of CLCuV DNA â (Table 2). Denaturation was done at 94°C and annealing at 56 °C for 1 minute; Elongation at 72 °C for 1minute (35 cycles) and final elongation at 72 °C for 7-10 minutes.

RESULTS AND DISCUSSION

Effect of JA and SA doses on total leaf protein content (mg/g fr. wt.) in different cotton accessions at various time intervals. : The data pertaining to changes in protein concentration recorded at periodical interval of 24 hrs till a week in response to various doses of JA and SA *i.e.* 50 µM, 100 µM, 150 µM and 200 µM revealed statistically significant differences amongst the various doses applied (Table 3, 4, 5, 6 and 7). Amongst the treatments applied, JA caused highest increase in protein content in accession LD 694 (2.3 fold) followed by PIL 8 (2 fold), RS 921 (2 fold), ANKUR 3028 BGII (1.6 fold), and LH 2076 (1.6 fold) whereas SA resulted in 1.4, 1.1, 1.2, 1.2 and 1.4 fold increase in protein concentration with respect to control in PIL 8, RS 921, ANKUR 3028 BGII, and LH 2076 indicating that JA is a better inducer of proteins.

Statistically significant differences in protein concentrations at different doses of each treatment were observed as indicated in Fig 1, 2, 3, 4 and 5 respectively JA resulted in mean maximum protein content *i.e* 15.1, 13.1, 15.0, 12.0 and 11.5 mg/g fr. wt. at 150 ìM whereas SA resulted in mean maximum protein value (9.0, 8.0, 8.6, 8.5 and 6.4 mg/g fr. wt.) at 200 ìM of SA when compared with control value of protein (5.8, 6.6, 5.1, 6.5 and 4.0 mg/g fr. wt.) in accession RS 921, LH 2076, PIL 8, ANKUR 3028 BGII and LD 694, respectively.

It was observed that 150 ìM of JA and 200 ìM of SA resulted in highest protein induction in all the treated accessions as compared to their controls. Comparative analysis of mean protein induction in different cotton accessions treated with 150 ìM of JA and 200 ìM SA after a week

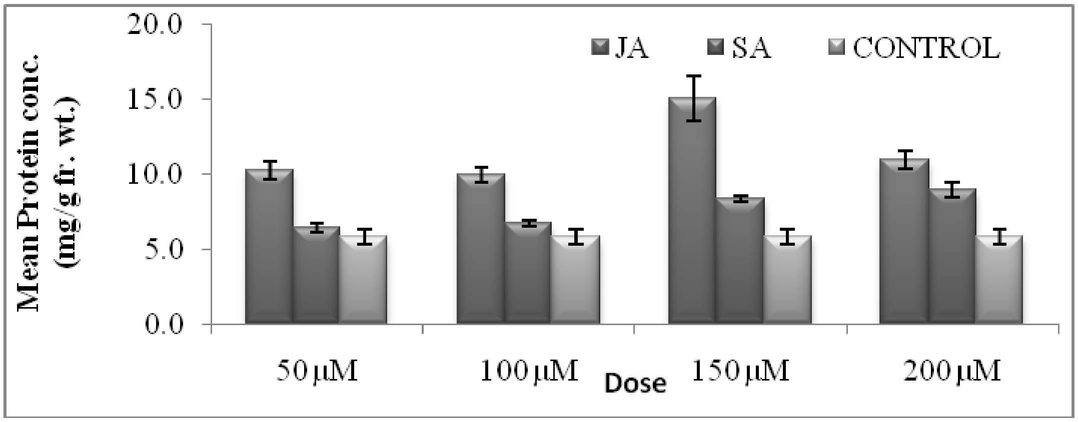


Fig 1 Effect of different doses of JA and SA on protein concentration of *G. hirsutum* accession RS 921
*Each value is a mean (Three replications) of values of protein concentration at different doses of each treatment

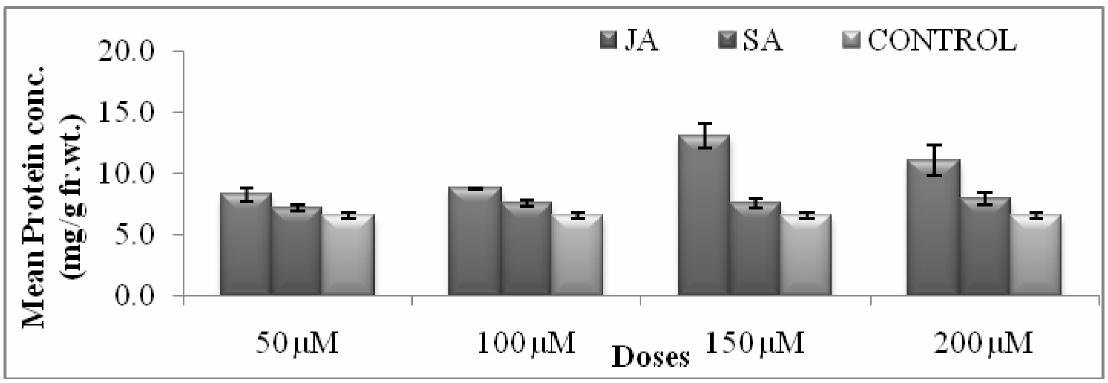


Fig 2 Effect of different doses of JA and SA on protein concentration of *G. hirsutum* accession LH 2076
*Each value is a mean (Three replications) of values of protein concentration at different doses of each treatment

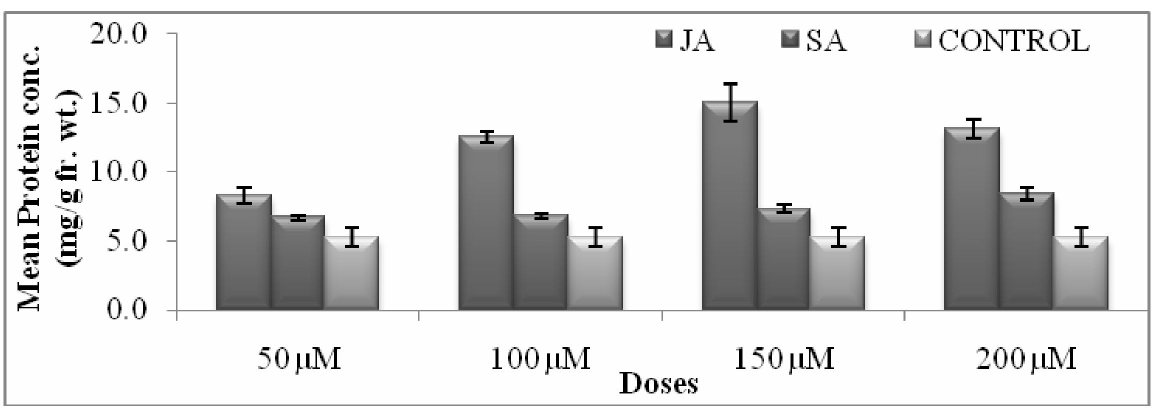


Fig 3 Effect of different doses of JA and SA on protein concentration of *G. hirsutum* accession PIL 8
*Each value is a mean (Three replications) of values of protein concentration at different doses of each treatment

interval as shown in Fig 6 revealed highest protein induction in RS 921 and PIL 8 followed by Ankur 3028 BGII and LH 2076. Similar results were obtained when cotton accessions were treated with 200 ìM of SA. Treatment with 150 ìM of JA resulted in 15.1, 15.0, 13.1, 12.0 and

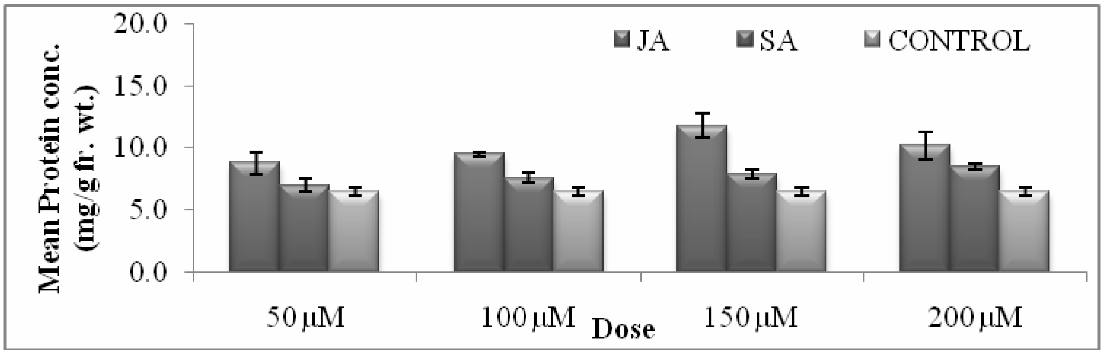


Fig 4 Effect of different doses of JA and SA on protein concentration of *G. hirsutum* accession Ankur 3028 BGII
*Each value is a mean (Three replications) of values of protein concentration at different doses of each treatment

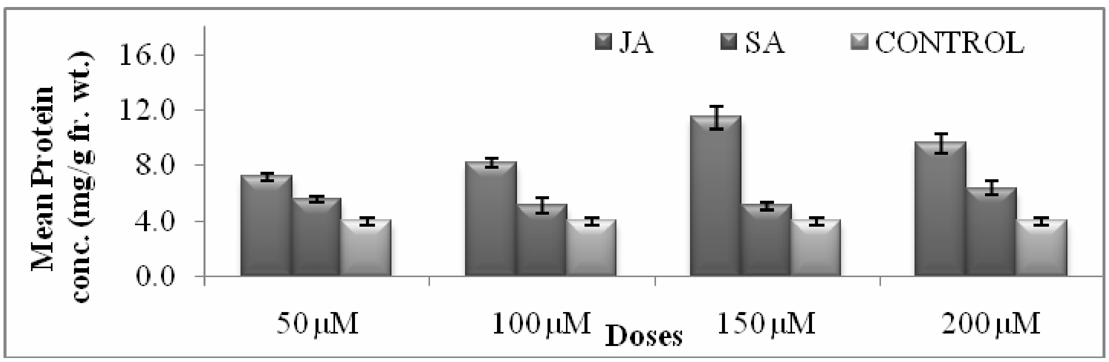


Fig 5 Effect of different doses of JA and SA on protein concentration of *G. arboreum* accession LD 694
*Each value is a mean (Three replications) of values of protein concentration at different doses of each treatment

11.5 mg/g fr. wt. protein in RS 921, PIL 8, LH 2076, Ankur 3028 BGII and LD 694 whereas 200ìM of SA resulted in 9.0, 8.6, 8.0 , 8.5 and 6.4 mg/g fr. wt. protein in RS 921, PIL 8, LH 2076, Ankur 3028 BGII and LD 694 respectively as compared to protein values in control which were 5.8, 5.2, 6.6, 6.5 and 4.0 mg/g fr. wt.

This induction of proteins in different accessions is well supported with the fact that the known phytohormones JA and SA are found

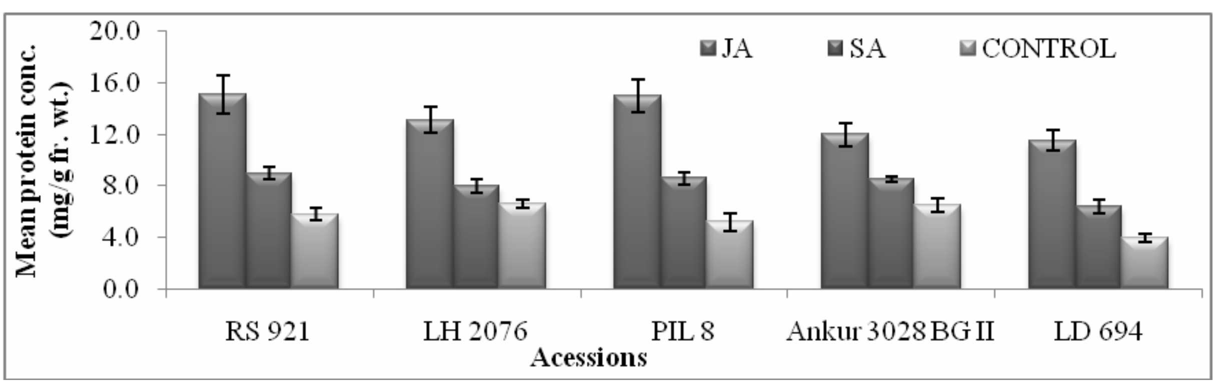


Fig 6 Comparative protein content in different cotton accessions with respect to 150 ìM of JA and 200 ìM of SA after a week interval

List of Abbreviations

AlMV	Alfalfa mosaic virus
BtMV	Beet mosaic virus
CLCuD	Cotton leaf curl disease
CLCuV	Cotton leaf curl virus
CMV	Cucumber mosaic virus
CTAB	Cetyl trimethyl ammonium bromide
DNA	Deoxyribonucleic acid
HCl	Hydrochloric acid
Hrs	Hours
JA	Jasmonic acid
JIP	Jasmonic acid induced proteins
kDa	Kilo Dalton
mg/g fr. Wt.	Milligram per gram of fresh weight
mM	Milimolar
PCR	Polymerase chain reaction
PR proteins	Pathogenesis-related proteins
Rpm	Revolutions per minute
SA	Salicylic acid
SAR	Systemic acquired resistance
SDS-PAGE	Sodium dodecyl sulphate polyacry lamide gel electrophoresis
TCV	Turnip crinkle viruse
iM	Micromolar

to regulate plant responses to biotic and abiotic stresses. JA and its metabolites are known to activate plant defence by the induction of jasmonate induced proteins and PR proteins (Delker 2006). Exogenous application of SA was shown to be mimicking certain aspects of a pathogen infection, resulting in SAR gene expression (Vernooij *et al* 1995). Uknes *et al* (1992) also stated the involvement of SA in SAR which activated gene expression of various defensive factors such as induction of PR proteins. Treatment with jasmonates was shown to induce various responses including the accumulation of serine proteinase inhibitors (Farmer 1990), leucine aminopeptidase and threonine deaminase (Hildmann *et al* 1992), phenylalanine ammonia-lyase, thionin (Anderson *et al* 1992), ribosome-inactivating protein (chaudhry *et al* 1994) and number of secondary metabolites were also shown to

Table 1 (a) Cotton leaf curl disease rating scale

Rating scale	Symptoms
0	Plants free from CLCuD
1	Thickening of small veins, only few upper leaves affected
2	Thickening of veins, curling and cupping of leaves
3	Thickening of veins, curling and cupping of leaves, enation development on underside of leaves
4	Thickening of veins, cupping, enations, stunting of plants and few bolls

Table 1 (b). Cotton leaf curl disease rating scale

Per cent disease index	Reaction
0	Highly resistant (HR)
0.01-5	Resistant (R)
5.1-25	Moderately Resistant (MR)
25.1-50	Moderately Susceptible (MS)
>50	Susceptible (S)

Table 2 Sequence DNA â specific primer pair used in the study

Source	Primer	Base sequence (5’-3’)
AY083590.1	â 1 (F)	ACCGTGGGCGA GCGGTGCCCGAT
	â 1 (R)	CACGTGTAAT ACGTCTCCATCGTC

accumulate in cultured cells of various plant species upon treatment with JA (Gundlach 1992). It was found by Jing shi *et al.,* (2010) that exogenous application of JA and SA resulted in the induction of proteins in transgenic *Nicotiana benthamiana* with the expression of GhMPK7 gene. Haggag *et al.,* (2010) in their work reported that MeJA application on to the Beet mosaic virus (BtMV) infected sugarbeet plants resulted in the accumulation of total soluble proteins, chitinases etc which belong to various PR families. Yamada *et al.,* (2012) also reported that treatment of rice plants with jasmonates results in the induction of OsJAZ8 protein. White (1979) reported the accumulation of PR proteins in tobacco plants which were treated with SA. SA and its structural analogue BTH are successfully used in inducing protection against various plant viruses like Tobacco mosaic virus (TMV) in tobacco, Turnip crinkle virus (TCV) in *Arabidopsis* (Lawton *et al* .,1996), and Cucumber mosaic virus (CMV) in tomato (Anfoka, 2000).

Comparative analysis of electrophoretic profile of cotton accessions treated with JA and SA : Extracted cotton leaf proteins were subjected to SDS-PAGE electrophoresis. Leaf samples of treated accessions namely RS 921, LH 2076, PIL 8, Ankur 3028 BGII and LD 694 which showed maximum protein induction at 150 µM of JA and 200 µM of SA were evaluated for protein profiling through SDS-PAGE. Total leaf proteins were resolved in molecular weights in the range 6-180 kDa *w.r.t* standard protein marker. Specific bands falling in the range of 6-49 kDa were reported in treated samples as compared to their respective control as shown in Plate 1 and Plate 2. It is known that PR proteins fall under the range of 15.8 kDa to 45 kDa (Van Loon and Antoniw 1982). Bol *et al* (1990) reported the induction of various PR proteins of molecular size ranging from 15.8-45 kDa with the application of SA in Tobacco plants. Jishan *et al* (2011) also revealed the induced expression of defence related genes like PR 2, PR 3, PR 5, PR 10 and Ta-JA2 which encode â,1-3 glucanase, chitinase, thaumatin-like protein, peroxidase etc. in different wheat accessions- namely Chinese Spring, Pumai 9 and Zhoumai 18 with MeJA treatment. Schweizer *et al* (1993) reported that in barley *(Hordeum vulgare* L.*)* application of Jasmonic acid effectively protected it against subsequent infection of *Erysiphe graminis* f.sp.

Table 3 Effect of different doses of JA and SA on leaf protein concentration (mg/g fr. wt. of *G. hirsutum* accession RS 921 recorded at periodic time intervals

Dose	Treatment	Time interval (h)					**Treatment mean**
		24	48	72	96	Week	
50 iM	JA	9.0	9.5	9.9	10.3	12.6	**10.3**
	SA	5.7	6.0	6.2	6.7	7.4	**6.4**
	Water	4.3	5.3	6.2	6.4	7.0	**5.8**
100 iM	JA	9.2	9.3	9.5	10.4	11.7	**10.0**
	SA	6.3	6.5	6.7	6.8	7.3	**6.7**
	Water	4.3	5.3	6.2	6.4	7.0	**5.8**
150 iM	JA	11.6	12.4	15.5	16.3	19.9	**15.1**
	SA	8.0	8.1	8.2	8.5	9.3	**8.4**
	Water	4.3	5.3	6.2	6.4	7.0	**5.8**
200 iM	JA	9.9	10.0	10.6	11.8	12.8	**11.0**
	SA	8.1	8.4	8.6	9.4	10.6	**9.0**
	Water	4.3	5.3	6.2	6.4	7.0	**5.8**

CD(0.05) Dose (A) = 0.056, Treatment (B) = 0.048, (A)(B) = 0.0097

Table 4 Effect of different doses of JA and SA on leaf protein concentration (mg/g fr. wt.) of *G. hirsutum* accession LH 2076 recorded at periodic time intervals

Dose	Treatment	Time interval (h)					**Treatment mean**
		24	48	72	96	Week	
50 iM	JA	7.2	7.5	8.1	8.5	10.3	**8.3**
	SA	6.6	6.8	7.1	7.5	7.9	**7.2**
	Water	6.0	6.3	6.5	6.6	7.6	**6.6**
100 iM	JA	8.5	8.7	8.8	8.9	9.0	**8.8**
	SA	6.7	7.2	7.6	8.0	8.3	**7.6**
	Water	6.0	6.3	6.5	6.6	7.6	**6.6**
150 iM	JA	11.0	11.9	12.7	13.3	16.7	**13.1**
	SA	6.6	7.0	7.5	8.0	8.7	**7.6**
	Water	6.0	6.3	6.5	6.6	7.6	**6.6**
200 iM	JA	8.8	9.0	9.8	13.3	14.7	**11.1**
	SA	6.8	7.1	7.9	8.9	9.3	**8.0**
	Water	6.0	6.3	6.5	6.6	7.6	**6.6**

CD(0.05) Dose (A) =0.039, Treatment (B) = 0.034, (A)(B) = 0.0.069

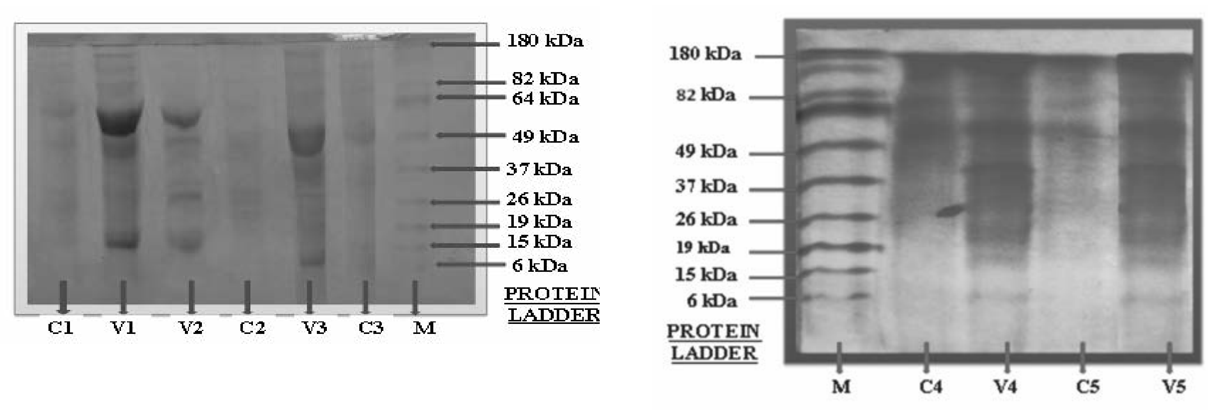


Fig 7. SDS-PAGE of leaf proteins of different cotton accessions at 150 ìM of JA
M- Protein Ladder (6 kDa- 180 kDa), V1- Ankur 3028 BGII, V2- LH 2076, V3- LD 694, V4- RS 921, V5- PIL 8; C1, C2, C3, C4, C5 represent control of Ankur 3028 BGII, LH 2076, LD 694, RS 921 and PIL 8 accessions

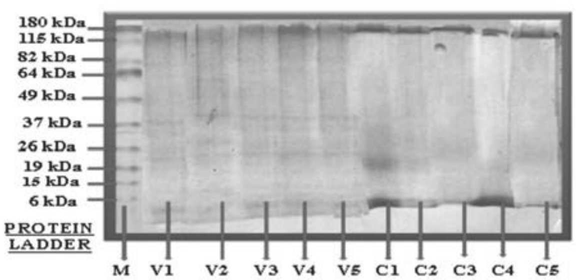


Fig 8. SDS-PAGE of leaf proteins of different cotton accessions at 200 ìM of SA
M- Protein Ladder (6 kda- 180 kDa), V1- PIL 8, V2- RS 921, V3- LH 2076, V4- Ankur 3028 BGII, V5- LD 694; C1, C2, C3, C4, C5 – represent control of PIL 8, RS 921, LH 2076, Ankur 3028 BGII and LD 694 accessions

hordei by resulting in the formation of JA induced proteins (JIP) and Pathogenesis related proteins (PR). Two prominent groups of proteins of molecular size 25 kDa and 10 to 12 kDa sizes were induced. Exogenously applied MeJA imparted protection against *Alternaria brassicicola* in *Arabidopsis* by the induction of PDF1.2 PR-3 and PR-4 gene (Thomma *et al.,* 1998). Thus, it showed that exogenous application of JA and SA resulted in the induction of PR proteins of molecular size ranging from 15.8-45 kDa along with some other proteins as well in all the cotton accessions under treatment which might be including proteins specifically for virus control. The proteins acting against virus could include peroxidises, polyphenol oxidases or other PR proteins (Thaler *et al* 2002).

Effect of JA and SA on disease incidence and severity of CLCuD : Effect of JA and SA applied at a concentration of 150 μM on the incidence and severity of CLCuD. At 150 μM of JA and SA disease incidence and severity values were observed to be lower as compared to control in accessions RS 921, LH 2076 and Ankur 3028 BGII (Table 8). Disease incidence was (37%), (30%), (30%) and disease index was (48%), (40%), (40%) in RS 921, LH 2076, Ankur 3028 BGII at 150 μM concentration of JA which was (50%), (46%), (45%) and (78%), (65%), (63%) for disease incidence and disease index values in control. No disease was observed in PIL 8 and LD 694 cotton accessions.

Effect of 200 μM of JA and SA also

Table 5 Effect of different doses of JA and SA on protein concentration (mg/g fr. wt.) of *G. hirsutum* accession PIL 8 recorded at periodic time intervals.

Dose	Trea-tment	Time interval (h)					**Treat-ment mean**
		24	48	72	96	Week	
50 iM	JA	6.9	7.6	8.2	8.7	9.9	**8.3**
	SA	6.3	6.4	6.7	6.7	7.3	**6.7**
	Water	3.3	4.3	5.8	6.2	7.0	**5.2**
100 iM	JA	11.7	12.0	12.3	12.7	13.9	**12.5**
	SA	6.5	6.6	6.7	6.9	7.3	**6.7**
	Water	3.3	4.3	5.8	6.2	7.0	**5.2**
150 iM	JA	11.9	13.3	14.1	16.1	19.6	**15.0**
	SA	6.7	6.9	7.2	7.7	8.2	**7.3**
	Water	3.3	4.3	5.8	6.2	7.0	**5.2**
200 iM	JA	11.6	12.4	12.9	13.4	15.4	**13.1**
	SA	7.3	7.6	8.4	8.8	9.9	**8.6**
	Water	3.3	4.3	5.8	6.2	7.0	**5.2**

CD(0.05)
Dose (A) = 0.04, Treatment (B) = 0.03, (A)(B) = 0.07

Table 6 Effect of different doses of JA and SA on protein concentration (mg/g fr. wt.) of *G. hirsutum* accession Ankur 3028 BGII recorded at periodic intervals

Dose	Trea-tment	Time interval (h)					**Treat-ment mean**
		24	48	72	96	Week	
50 iM	JA	7.1	7.9	8.0	9.0	12.0	**8.8**
	SA	6.0	6.2	6.5	7.7	8.6	**7.0**
	Water	5.9	6.0	6.3	7.0	7.5	**6.5**
100 iM	JA	9.0	9.2	9.5	9.9	10.0	**9.5**
	SA	6.6	6.9	7.6	7.9	8.8	**7.6**
	Water	5.9	6.0	6.3	7.0	7.5	**6.5**
150 iM	JA	9.6	10.8	11.1	12.6	15.0	**12.0**
	SA	7.0	7.5	7.9	8.3	9.0	**7.9**
	Water	5.9	6.0	6.3	7.0	7.5	**6.5**
200 iM	JA	8.4	8.6	8.8	11.4	14.0	**10.2**
	SA	8.0	8.1	8.5	8.9	9.0	**8.5**
	Water	5.9	6.0	6.3	7.0	7.5	**6.5**

CD(0.05)
Dose (A) = 0.033, Treatment (B) = 0.029, (A)(B) = 0.058

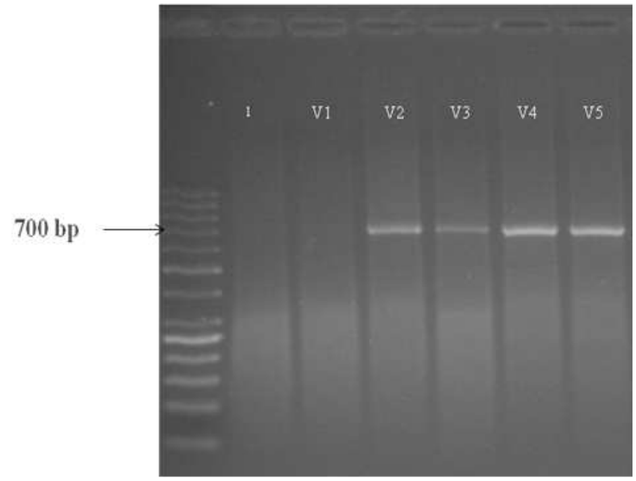


Fig 9 Detection of latent carryover of CLCuD in symptomless plants of different cotton accessions treated with 150 iM of JA through PCR based amplification using primer â
1- Negative control, V1- LD 694, V2- RS 921, V3- LH 2076, V4- PIL 8, V5- Ankur 3028 BGII

Table 7 Effect of different doses of JA and SA on protein concentration (mg/g fr. wt.) of *G. arboreum* accession LD 694 recorded at periodic intervals

Dose	Trea-tment	Time interval (h)					**Treat-ment mean**
		24	48	72	96	Week	
50 iM	JA	6.3	6.9	7.1	7.5	8.0	**7.2**
	SA	5.0	5.3	5.6	6.0	6.3	**5.6**
	Water	3.6	3.7	3.8	3.9	5.0	**4.0**
100 iM	JA	7.2	7.7	8.3	8.8	9.0	**8.2**
	SA	3.9	4.3	4.6	5.6	6.9	**5.1**
	Water	3.6	3.7	3.8	3.9	5.0	**4.0**
150 iM	JA	9.7	10.3	11.2	12.0	14.4	**11.5**
	SA	4.4	4.6	5.1	5.5	5.7	**5.1**
	Water	3.6	3.7	3.8	3.9	5.0	**4.0**
200 iM	JA	7.3	8.8	10.0	10.4	11.5	**9.6**
	SA	5.4	5.7	6.0	6.6	8.1	**6.4**
	Water	3.6	3.7	3.8	3.9	5.0	**4.0**

CD(0.05)
Dose (A) = 0.041, Treatment (B) = 0.036, (A)(B) = 0.072

indicated lower disease incidence and severity as compared to control (Table 9). At 200 iM SA disease incidence was (48%), (36%), (34%) and disease index was (57%), (50%), (50%) in RS 921, LH 2076, Ankur 3028 BGII which was (50%), (46%), (45%) and (78%), (65%), (63%) when

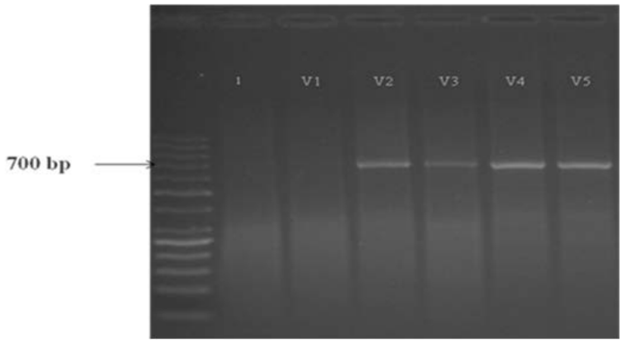


Fig 10 Detection of latent carryover of CLCuD in symptomless plants of different cotton accessions treated with 200 ìM of SA through PCR based amplification using primer â
1- Negative control, V1- LD 694, V2- RS 921, V3- LH 2076, V4- PIL 8, V5- Ankur 3028 BGII

compared with disease incidence and disease index values of control. Greater disease inhibition in disease incidence and severity was observed at 150 ìM of JA and 200 ìM of SA which was found to be negatively correlated with the amount of protein induced at these concentrations as at above mentioned concentration maximum protein induction was observed which could be responsible in lowering the disease. This decrease in disease parameters due to the induction of PR proteins and some other proteins is well supported by the findings of Chandra *et al* (2001) who showed that foliar spray of 0.02 per cent of SA twice at a week interval caused reduction in root rot disease caused by *Rhizoctonia solani* by enhancing the production of proteins. Spraying tobacco with SA induced the production of PR-1 proteins which played role in inhibiting the multiplication of alfalfa mosaic virus (AlMV) (Huijsduijnen *et al* 1986). Faheed *et al* (2006) reported that exogenous application of 0.1, 0.5 and 1mM SA

Table 8 Effect of JA and SA at a dose of 150 ìM on disease incidence and severity of CLCuD.

Cultivar	Disease Incidence (%) Dose @ 150 ìM									Disease Index (%)		
	14 *DAS			21 DAS			28 DAS					
	Control	JA	SA	Control	JA	SA	Control	JA	SA	Control	JA	SA
RS 921	20	0	37	40	27	50	50	37	75	78	48	60
LH 2076	0	0	0	20	25	37	46	30	62	65	40	53
PIL 8	0	0	0	0	0	0	0	0	0	0	0	0
Ankur 3028 BGII	0	0	0	28	20	33	45	30	55	63	40	50
LD 694	0	0	0	0	0	0	0	0	0	0	0	0

*DAS - Days after spray

Table 9 Effect of JA and SA at a dose of 200 ìM on disease incidence and severity of CLCuD

Cultivar	Disease Incidence (%) Dose @ 150 ìM									Disease Index (%)		
	14 *DAS			21 DAS			28 DAS					
	Control	JA	SA	Control	JA	SA	Control	JA	SA	Control	JA	SA
RS 921	20	0	12	40	35	32	50	45	48	78	50	57
LH 2076	0	0	0	20	16	15	46	33	36	65	48	50
PIL 8	0	0	0	0	0	0	0	0	0	0	0	0
Ankur 3028 BGII	0	0	0	28	25	28	45	32	34	63	45	50
LD 694	0	0	0	0	0	0	0	0	0	0	0	0

*DAS - Days after spray

on two week old plants of *Phaseolus vulgaris* induced partial inhibition in the accumulation of virus and elevated the induction of various total soluble proteins as compared to untreated plants which resulted in the induction of resistance against TNV. Resistance against the pathogen was attributed to the induction of proteins belonging to PR-2, PR-4 and PR-8 family.

Detection of latent carryover of CLCuD : Total DNA from symptomless plants of different cotton accessions which were earlier treated with 150 ìM of JA and 200 ìM of SA at which maximum protein induction was observed revealed the presence of a DNA â major band of about 600-700 bases in all the cotton accessions except LD 694 which indicated the presence of virus in all the cotton accessions except accessions *desi* cotton variety LD 694 (Fig 9 and Fig 10) which signified that PR proteins do not eliminate the virus. Earlier, Sabhiki *et al* (2004) also confirmed the presence of latent infection of CLCuV in apparently disease free plants and healthy plants of resistant genotypes.

The present study suggests that application of JA and SA results in the induction of proteins of different molecular weights which probably resulted in imparting tolerance against CLCuD whereas, PCR analysis showed that induced proteins were not able to eliminate the presence of virus particles. So, we can say that these chemicals can be used as an alternate to viricides in near future.

REFERENCES

Andresen I, Becker W, Schluter K, Burges J, Parthier B and Apel K 1992. The identiûcation of leaf thionin as one of the main jasmonate-induced proteins of barley (*Hordeum vulgare*). *Plant Mol Biol* 19: 193-204.

Anonymous 2008. All India Coordinated Cotton Improvement Project. Annual Report, CICR, Coimbatore.

Anup Inder Kaur 2013. *Identification and Characterization of DNA â Cotton Leaf Curl Disease Complex*, M.Sc. Thesis, Punjab Agricultural University, Ludhiana .

Bol J F, Linthorst H J M and Cornelissen B J C 1990. Plant pathogenesis related proteins induced by virus infection. *Annu Rev Phytopathol* 28: 113-138.

Chandra A, Anand A, Mandal P K and Saxena P 2001. Influence of salicylic acid on protein content and catalase activity in relation to systemic acquired resistance in cowpea against root rot. *Indian Phytopath.* **54 :** 284-87.

Chaudhry B, Muller F, Cameron-Mills V, Gough S, Simpson D, Skriver K and Mundy J. 1994. The barley 60 kDa jasmonate-induced protein (JIP60) is a novel ribosome-inactivating protein. *Plant J.* **6 :** 815–24.

Cohen Y, Gisi U and Niderman T. 1993. Local and systemic protection against *Phytopthora infestans* induced in potato and tomato plants by Jasmonic acid and Jasmonic methyl ester. *Phytopathology.* **83 :** 1054-62.

Delker C. 2006. Jasmonate biosynthesis in *Arabidopsis thalaina*- enzymes, products and regulation. *Plant biol* **8 :** 297-306.

Dixon R A. 1986. The phytoalexin response: elicitation, signaling and control of host gene expression. *Biol Rev Cambridge Philos Soc.* **61 :** 239-92.

Durrant W E and Dong X. 2004. Systemic Acquired Resistance. *Annu Rev Phytopathol.* **42 :** 185-209.

Faheed F A and Mahmoud S Y M. 2006. Induction of resistance in *Phaseolus vulgaris* against TNV by salicylic acid and kinetin. *Int J Agri and Bio.* **8:** 47-51.

Farmer E E and Ryan C A. 1990. Interplant communication: airborne methyl jasmonate induces synthesis of proteinase inhibitors in plant leaves. *Proc Natl Acad Sci* USA. **87 :** 7713.

Gundlach H, Muller M J, Kutchan T M and Zenk M H. 1992. Jasmonic acid is a signal transducer in elicitor- induced plant cell cultures. *Proc Natl Acad Sci* USA. **89 :** 2389–93.

Haggag W M, Mahmoud Y S and Farag E M. (2010). Signaling Necessities and Function of Polyamines/Jasmonate-Dependent Induced Resistance in Sugar Beet against Beet Mosaic Virus (BtMV) Infection. *J New York Sci* 3: 95-103.

Hildmann T, Ebneth M, Pen A,Cortes H, Sanchez Serrano J J, Willmitzer L and Prat S. 1992. General role of abscisic and jasmonic acids in gene activation as a result of mechanical wounding. *Plant Cell.* **4:** 1157–70.

Huijsduijnen R A M H V, Alblas S W, Rijk R H D and Bol J F. 1986. Induction of salicylic acid of pathogenesis related proteins and resistance to alfalfa mosaic virus infection in various plant species. *J gen virol.* **67 :** 2135-43.

Jing S, Hai-long A, Liang Z, Zheng Gao and Xing-Qi G. 2010. GhMPK7, a novel multiple stress responsive cotton group C MAPK gene has a role in broad spectrum disease resistance and plant development. *Plant Mol Biol.* **74 :** 1-17.

Jishan N, Jing L, Wenben M, Qiao Y L, Zhengyang W and Dexian H. 2011. The relationship of methyl jasmonate enhanced powdery mildew resistance in wheat and the expressions of 9 disease resistance related genes. *Agric Sci Tech* **12** : 504-08.

Kessmann H, Staeeb T, Hofmann C, Maetzke T and Herzog J. (1994). Induction of systemic acquired disease resisrance in plants by chemicals. *Ann Rev Phytopathol.* **32:** 439-59.

Kuc J. 2001. Concepts and direction of induced systemic resistance in plants and its application. *Eur J plant Pathol.* **107:** 7-12.

Lawton K, Freidrich L, Hunt M, Weymann K, Delaney K, Kessmann H, and Ryals J. 1996. Benzothiadiazole induces disease resistance in *Arabidopsis* by activation of systemic acquired resistance signal transduction pathway. *Plant J.* **10:** 71-82.

Lowry O H, Rosebrough N J, Farr A L and Randal R J. 1951. Protein measurement with folin phenol reagent. *J Biol Chem.* **198 :** 265-75.

Ryals J A, Neuenschwander U H, Willits M G, Mlina A, Steiner H Y and Hunt M D. (1996). Systemic acquired resistance. *The Plant cell.* **8 :** 1809-19.

Sabhiki H S, Sekhon P S, Gupta V K and Sohu R S. 2004. Identification of cotton leaf curl immune genotypes in *Gossypium hirsutum. Crop Improv.* **31:** 66-70.

Schweizer P, Gees R, Mosinger E. 1993. Effect of Jasmonic acid on the interaction of Barley (*Hordeum vulgare L.*) with the powdery mildew *Erysiphe graminis f.sp. hordei. Plant Physiol.* **102 :** 503-11.

Shaghai-Maroof M A, Soliman K M, Jorgensen R A and Allard R W. 1984. Ribosomal DNA spacer-length polymorphism in barley: Mendelian inheritance, chromosomal location, and population dynamics. *Proc Natl Acad Sci* USA. **81:** 8014-18.

Sticher L, Mauch-mani B and Metraux J P. 1997. Systemic acquired resistance. *Ann Rev of Phytopathol.* 35: 235-270.

Thaler J S, Fidantsef A L and Bostock R M. 2002. Antagonism between jasmonate and salicylate mediated induced plant resistance: effects of concentration and timing of elicitation of defense-related proteins, herbivore, and pathogen performance in tomato. *Journal Chemical Ecology*. 28: 1131–1159.

Thomma Bart P H J, Eggermont K, Penninckx Iris A M A, Mauch-Mani B, Vogelsang R, Cammue Bruno P A and Broekaert W F. 1998. Separate Jasmonate-dependent and Salicylate-dependent defense-response pathways in *Arabidopsis* are essential for resistance to distinct microbial pathogens. *Proc Natl Acad Sci USA.* 95:15107-15111.

Uknes S, Mauch-mani B, Moyer M, Potter S and Williams S. **1992.** Acquired resistance in *Arabidopsis*. *Plant Cell.* **4 :** 645-56.

Van Loon L C and Antoniw J F. 1982. Comparison of the effects of salicylic acid and ethephon with virus induced hypersensitivity and acquired resistance in tobacco. *Neth J Plant Pathol.* **88 :** 237-256.

Van-wees, De S A M, Van P J A, Van L and Pieterse C M J. 2000. Enhancement of induced disease resisance by simultaneous activation of salicylate and jasmonate dependent defense pathways and in *Arabidopsis thalaina. Proc Natl Acad Sci* USA . **97 :** 8711-16.

Vernooij B, Freidrich L, Morse A, Ahl goy P, staub T, Kessmann H and Ryals J. **1995**. 2,6-Dichloroisonicotinic acid induced resistance to pathogens without the accumulation of salicylic acid. *Mol Plant Microbe Interact* **8 :** 2228-34.

Walker J M. 1996. SDS polyacrylamide gel electrophoresis of proteins. In: Walker J M (ed) The protein protocols handbook pp 55-61. Humana Press Inc. Totowa N J.

Wang K, Weaver N D, Kesarwani M and Dong X 2005. Induction of protein secretory pathway is required for systemic acquired resistance. *Science* 308: 1036-1040.

White R F. 1979. Acetylsalicylic acid (aspirin) induces resistance to tobacco mosaic virus in tobacco. *Virol.* **99:** 410-412.

Yamada S, Kanol A, Tamaoki D, Miyamoto A, Shishido H, Miyoshi S and Gomi K. 2012. Involvement of OsJAZ8 in jasmonate-induced resistance to bacterial blight in rice. *Plant Cell Physiol.* 53: 2060-2072.

Anfoka G H. 2000. Benzo-(1, 2, 3)-thiadiazole-7-carbothioic acid S-methyl ester induces systemic resistance in tomato (*Lycopersicon esculentum* Mill cv. vollendung) to Cucumber mosaic virus. *Crop Prot* **19:** 401-05.

Detection of pink bollworm, *Pectinophora gossypiella*, Saunders infestation using Soft X ray machine

S. NANDINI AND S. MOHAN
Tamil Nadu Agricultural University, Fertilizer Control Laboratory, Coimbatore - 641 003
E-mail : nandhunannu@gmail.com

ABSTRACT : An experiment was carried on standardization of X ray radiography methodology for the detection of pink bollworm infestation in cotton bolls during 2012-2014 at Indian Institute of Crop Processing Technology, Thanjavur, Tamil Nadu, India. Studies revealed that the controllable input electrical parameters of the X ray machine *viz.*, voltage, current and exposure period required for the detection of internal infestation varied widely for cotton bolls compared to stored grains and fruits tested by other scientists. High voltage and current were required for dense cotton bolls to ensure adequate penetration of radiation. It was observed on visual analysis that the X ray radiation generated at 80 kV and 10 mA for 30 seconds resulted in the best visual images to view internal content of cotton bolls and observed to be the best for cotton bolls imagery out of 96 combinations tested for best detection of hidden infestation. While other combinations, for example, 60Kv, 4mA for 10 seconds and 90 Kv, 10mA for 30 seconds manifested into lighter and darker images, respectively.

Key words : Infestation, non destructing sampling, pink bollworm, X ray

Cotton, *Gossypium hirsutum* L., popularly called as “King of fibres” or “White gold” and it is cultivated in an area of 116.14 lakh hectare with an average production of 334 lakh bales in India (Anonymous, 2013). About 130 different species of insects and mites are reported to cause damage to cotton crop in India (Agarwal *et al.,* 1984). Among these, the bollworms *viz.,* american bollworm, *Helicoverpa armigera* (Hubner), spiny bollworm, *Earias insulana* (Boisdual), spotted bollworm, *Earias vitella* (Fabricius), pink bollworm, *Pectinophora gossypiella* (Saunders) pose greater threat to cotton production. Among the bollworms, the pink bollworm assumed major pest status in recent past (Gutierrez *et al.*, 2006). Further pink bollworm has become economically the most destructive and quarantine insect pest of cotton. Infestation of pink bollworm in cotton bolls cannot be seen through naked eyes because, the nature of PBW was soon after hatching larva enters the developing bolls through tip portion and entrance hole is closed as the boll mature. Therefore, infestation could not be seen, a kind of hidden infestation. Destructing sampling was the only conventional method for assessment of cotton boll damage. Hence, considering the importance and usefulness of non-destructive method of detecting (Milner *et al.*,1950; Schatzki and Fine, 1988; Haff and Slaughter, 1999) a laboratory experiment was undergone using X ray radiation.

X ray radiography provides a permanent, visible film record of the internal condition of the boll sample. It is especially useful for the rapid examination of relatively large samples to determine the extent of insect damage. X rays pass readily through the objects, although some of the radiation is absorbed and the amount of absorption depends on the density of the material, its thickness as well as the voltage applied to generate the X rays. For example, more radiation will pass through the areas containing hollow portions caused by insect tunneling than through the surrounding areas since the insect tunneling reduces the total thickness of the exposed material. High voltages are required to generate adequate penetration through very dense material. Adjustment of the voltage, current and exposure period to the specific material is important because it affects the contrast of the image recorded on X ray sensitive film after exposure. If the voltage, current and exposure period is too high, too much of the radiation will pass through the exposed material and obscure differences in thickness within the material. Similarly, contrast will be poor if the voltage, current and exposure period is too low since too little radiation will pass through the material to form a usable image (Ramakrishnan *et al.*, 2011). Although th technology is known and the suitable X ray machinery available, the input factors *viz.*, the voltage, current and the exposure period have not been standardized for cotton bolls. In the absence of standardized values of these input factors, users resort to standardization every time. Standardizing the methodology for a cotton boll is quite an important task to further the use of X ray radiography. Therefore, considering the importance and usefulness of this non-destructive method of detecting insect damage levels of pink bollworm in cotton bolls using soft X ray machine.

MATERIALS AND METHODS

Laboratory experiment for standardization of X ray radiography were proposed to be undertaken on the pink bollworm infestation in cotton bolls was conducted at Indian Institute of Crop Processing Technology, Ministry of Food Processing Industries, Thanjavur, Tamil Nadu, India. Cotton bolls for experimentation were collected from experimental farm, Tamil Nadu Agricultural University, Coimbatore.

Description and functioning of equipment X ray high tension transformer : The High Tension (HT) Transformer generated the high voltages required for the X ray generation. Transformer generated can be upto 160kV. The transformer was fully immersed in special purpose high electrical insulation transformer oil. The transformer was housed inside a separate chamber on wheels for easy movement. The output of the HT transformer was taken to the X ray tube head in the inspection Chamber using custom made insulated cables.

X Ray tube head : Tube head was internally cooled using HT oil. The tube head was coated with additional lead lining to prevent X ray leakage. The Tube Head was from where the X rays are generated.

Sample inspection chamber : The inspection chamber were samples are kept for inspection one after the other. This chamber was fully lead lined inorder to prevent X rays from escaping into the operator area. The X ray chamber has the X ray tube head, from where X rays emanate. It has the object plate, with sensor area marked. The door to the chamber was also lead lined. The door also has a leaded glass window, which was usefull to view the exact position for placing the object in the chamber. An interlocking limit switch was provided, which ensures that the X rays can be switched ON only when the window was closed. During exposure, window should be closed. The X ray protection for the X ray chamber was as per International Standard GB 18871.

X ray sensor : The X ray sensor was housed below the inspection chamber. Sensor was a digital sensor with 5 Mega Pixel resolutions. The area covered by the sensor was 150 x 150mm and was marked on the object plate. The output of the X ray sensor was provided to the PC using an USB port. The sensor was supported by software, where the parameters are changed for effectively viewing cotton bolls. The present investigations were intended to establish a methodology to facilitate the standardization of the X ray radiography and the input electrical parameters *viz.,* voltage (kV), current (mA) and exposure period (s). Required adjustments in voltage (kV), current (mA) and exposure period (s) in the X ray machine were effected during the exposure procedure. Once the exposure to radiation was done, the X ray film was processed with the help of chemicals for image development and image fixing.

Treatments and experiment procedure : Scientists at IICPT laboratories have found that fruit and vegetables require soft X ray radiations ranging from 60 to 90 kV at a current of 1 to 10 mA. The period of exposure also ranges between 10 and 55 seconds. Therefore, experiments were planned for cotton boll to find out a standard voltage, current and exposure period. The combination of 96 treatments was worked out and the same combinations were given. Image analysis was taken up for different combinations to find out and standardize the right one that gives us internal view of the cotton boll. Adjustments in combinations of current and exposure periods were made based on the preliminary image results while working in the laboratory.

RESULTS AND DISCUSSION

Out of ninety six different combinations of voltage, current and exposure period tried for cotton bolls infested with pink bollworm it was observed on visual analysis that the X ray radiation generated at 80 kV and 10 mA for 30 seconds resulted i the best visual images to view internal content of cotton bolls and observed to be the best for cotton bolls imagery out of 96 combinations tested for best detection of hidden infestation (Table 1). While other combinations, for example, 60Kv, 4mA for 10 seconds and 90 Kv, 10mA for 30 seconds manifested into lighter and darker images, respectively (Plate.1). In the plate 1, image with the combinations of 80 kV and 12 mA for 30 seconds, shows that the boll (bottom - left side) was found to be infested with 2nd instar PBW larva. Presence of insect stage will hide the internal content of the boll (enlarged image).

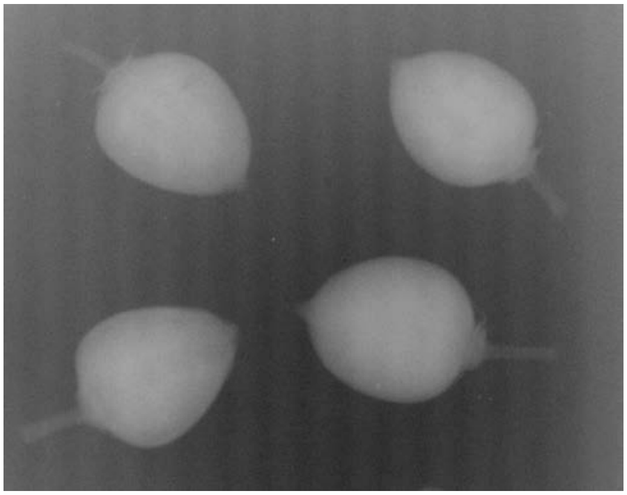
X ray radiography method is also used in detecting the hidden insect infestatio for it is also a non-destructive method. These techniques of X ray radiography were effectively used by Sarath Babu (1997) during quarantine processing of the germplasm imported from different countries and detection of several bruchids and chalcid species which were not reported from India. Similarly, this methodology was also used by Thomas *et al.,* (1995) on mango fruit infested with nut weevil, Shahin *et al.,* (2002) on apple, Karunakaran *et al.,* (2003a and 2003b) on western red spring wheat, on cherries and apple and on various fruits. Further investigations are necessary to carry out the brief usage of X ray radiography in detection of internal infestation of pink bollworm in cotton bolls. This study holds the basic research on non

Table 1. Treatment combinations of voltage, current and exposure period

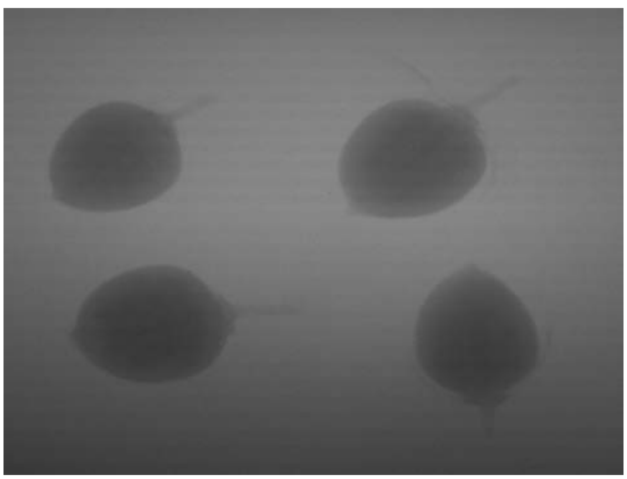
S. no	Kv	mA	S	S. no	Kv	mA	S	S. no	Kv	mA	S	S. no	Kv	mA	S
1	60	4	10	**26**	70	4	10	**51**	80	4	10	**76**	90	4	10
2	60	4	15	**27**	70	4	15	**52**	80	4	15	**77**	90	4	15
3	60	4	20	**28**	70	4	20	**53**	80	4	20	**78**	90	4	20
4	60	4	25	**29**	70	4	25	**54**	80	4	25	**79**	90	4	25
5	60	4	30	**30**	70	4	30	**55**	80	4	30	**80**	90	4	30
6	60	6	10	**31**	70	6	10	**56**	80	6	10	**81**	90	6	10
7	60	6	15	**32**	70	6	15	**57**	80	6	15	**82**	90	6	15
8	60	6	20	**33**	70	6	20	**58**	80	6	20	**83**	90	6	20
9	60	6	25	**34**	70	6	25	**59**	80	6	25	**84**	90	6	25
10	60	6	30	**35**	70	6	30	**60**	80	6	30	**85**	90	6	30
11	60	8	10	**36**	70	8	10	**61**	80	8	10	**86**	90	8	10
12	60	8	15	**37**	70	8	15	**62**	80	8	15	**87**	90	8	15
13	60	8	20	**38**	70	8	20	**63**	80	8	20	**88**	90	8	20
14	60	8	25	**39**	70	8	25	**64**	80	8	25	**89**	90	8	25
15	60	8	30	**40**	70	8	30	**65**	80	8	30	**90**	90	8	30
16	60	10	10	**41**	70	10	10	**66**	80	10	10	**91**	90	10	10
17	60	10	15	**42**	70	10	15	**67**	80	10	15	**92**	90	10	15
18	60	10	20	**43**	70	10	20	**68**	80	10	20	**93**	90	10	20
19	60	10	25	**44**	70	10	25	**69**	80	10	25	**94**	90	10	25
20	60	10	30	**45**	70	10	30	**70**	80	10	30	**95**	90	10	30
21	60	12	10	**46**	70	12	10	**71**	80						
22	60	12	15	**47**	70	12	15	**72**	80						
23	60	12	20	**48**	70	12	20	**73**	80						
24	60	12	25	**49**	70	12	25	**74**	80						
25	60	12	30	**50**	70	12	30	**75**	80						

destructing sampling method or X ray radiography. However there was a change in current and exposure period which may be attributed to built-in minor variations in different X ray machine used in experimentations. In future, we can expect precise work on detection of internal infestation of pink bollworm. Extensive work has been reported on the use of X rays to detect infestations in stored products due to internal grain feeders, the granary weevil, *Sitophilus granarius* Linnaeus, the rice weevil, *Sitophilus oryzae* L., the maize weevil, *Sitophilus zeamais* Mots., and the Angoumois grain moth, *Sitotroga cerealella* (Olivier) ingrain kernels by visual examination of the X ray radiographs (Keagy and Schatzki, 1991; Fenton and Waite, 1932). Only a few studies have used image processing algorithms to identify the insect infested wheat kernels using digital images of kernels (Karunakaran *et al.*, 2000; Keagy and Schatzki, 1993). From this context, the present findings are that X ray generated at 80 kV and 10 mA for 30 seconds resulted in the best visual images to view internal content of cotton bolls. Whereas, quarantine workers in India traditionally used only a range of 10 KV to 30 KV and a current of 4mA to 12mA for an exposure period of 10-25 seconds.

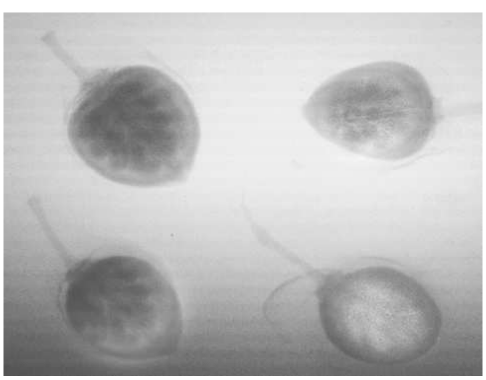
The range of X ray radiography values of about 20-34 KV, 12-30 mA current as optimum for the detection of stone weevil infestation in mango fruit. The present finding will form basis for Cotton Entomologist who want to work on



A) 1). 60 Kv 2). 4 mA 3). 10 s



B) 1). 90 Kv 2). 12mA 3). 30 s



C) 1). 80Kv 2). 12mA 3). 30 s

Plate 1. X ray radiography images of cotton with different combinations of A, B and C

detection of hidden infestation of cotton pink bollworm using soft X ray.

REFERENCES

Agarwal, R. A., G. P. Gupta and D. O. Grag. 1984. *Cotton Pest Management in India.* Research Publication, Azad Nagar, Delhi, pp. 1-191.

Anonymous, 2013. *"Annual Report (2012 -2013)".* All India Coordinated Cotton Improvement Project.

Fenton, F.A. and W.W. Waite. 1932. Detecting pink bollworms in cottonseeds by the X ray. *Jour. Agri. Res.* **45 :** 347-48.

Gutierrez. A.P., Sergine and Ponsard. 2006. Physiologically based demographics of Bt cotton–pest interactions I. Pink bollworm resistance, refuge and risk. *Ecological Modelling*, **191:** 346–59.

Haff, R.F and D.C. Slaughter. 1999. X ray inspection of wheat for granary weevils. ASAE Paper No. 99-3060. St. Joseph, MI: ASAE.

Karunakaran, C., D.S. Jayas and N.D.G. White. 2000. Detection of insect infestations in wheat kernels using soft X rays. CSAE/SCGR Paper No. AFL122. Winnipeg, MB: CSAE/SCGR.

Karunakaran, C., D.S. Jayas and N.D.G. White. 2003a. Soft Xray inspection of wheat kernels infested by *Sitophilus oryzae*. *Transactions ASAE,* **46** : 739-45.

Karunakaran, C., D.S. Jayas and N.D.G. White. 2003b. X ray image analysis to detect infestations caused by insects in grain. *Cereal Chemistry,* **80** : 553-57.

Keagy, P.M. and T.F. Schatzki. 1991. Effect of image resolution on insect detection in wheat radiographs. *Cereal Chemistry,* **68** : 339-43.

Keagy, P.M. and T.F. Schatzki. 1993. Machine recognition of weevil damage in wheat radiographs. *Cereal Chemistry,* **70** : 696-700.

Milner, M., M.R. Lee and R. Katz. 1950. Application of X ray technique to the detection of internal insect infestation of grain. *J. Econ. Entomol.,* **43** : 933-35.

Ramakrishnan, N., B, Sarath Babu and T. Ramesh Babu. 2011. Standardization of X ray Radiography Methodology for the Detection of Hidden Infestation in Cereals. *Ind. Jour.Plant Prot.* **39 :** 249-57.

Sarath Babu, B. 1997. Detection of insect pest of quarantine significance in screening of germplasm under exchange programme during 1989-1995 in India. *J. Entomol Res.,* **21 :** 295-97.

Schatzki, T.F and T.A. Fine. 1988. Analysis of radiograms of wheat kernels for quality control. *Cereal Chemistry,* **65** : 233-39.

Shahin, M. A., E. N. Tollner, R.W. Mcclendon and H. R. Arabnia. 2002. Apple classification based on surface bruises using image processing and neural networks. *Trans. ASAE,* **45 :** 1619-27.

Thomas, P., A. Kannan, V. H. Degwekar and M. S. Ramamurthy 1995. Non-destructive detection of seed weevil infested mango fruits by X ray imaging. *Postharvest Biology Tech.* **5 :** 161-65.

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Emerging insect pests of *Bt* cotton in middle Gujarat

M. B. ZALA, R. K. THUMAR, T. M. BHARPODA AND P. K. BORAD

Agricultural Research Station, Anand Agricultural University, Sansoli-387 130

E-mail: mkkasingh@gmail.com

To keep pace with increasing global need of cotton and food security, researchers have devised various technologies to make the cotton production more economic and sustainable. Efforts are being made to validate and disseminate these technologies among farmers. While extending these technologies there is a need to keep vigilance on the emerging pests under the changing cropping system and issue the periodical advisories for timely IPM intervention.

Due to changes in the agroecosystem, high inputs, reduced numbers and volume of insecticidal sprays, number of new insect pests are now claiming *Bt* cotton as their new host. In many parts of the country and the world, *Bt* cotton is under threat due to unusual attack of some insect pests. There are the possibilities of spread of the pests which may make a havoc, if due attention is not being given. In middle Gujarat,

Table 1. Activity of emerging insect pests in *Bt* cotton fields located in Vadodara and Kheda district during 2014 -2015 (Averaged over 18 fixed plots)

Month and week		Number of Mirid bug/ plant		Infested fruiting bodies due to pink bollworm (%)			
				Square		Green boll	
		Vadodara district	Kheda district	Vadodara district	Kheda district	Vadodara district	Kheda district
1		2	3	4	5	6	7
November	**II**	0.00	0.81	2.36	1.66	2.50	1.80
	III	0.00	0.00	2.51	0.09	2.98	0.05
	IV	0.00	0.08	2.93	0.16	3.50	0.12
December	**I**	0.00	0.28	2.87	1.18	4.25	0.96
	II	0.00	0.23	3.46	0.72	6.78	0.48
	III	0.00	0.18	4.23	0.34	12.33	0.28
	IV	0.00	0.13	5.46	0.31	17.69	0.19
January	**I**	0.00	0.00	6.77	0.84	20.21	0.23
	II	0.00	0.11	9.69	3.11	26.43	1.63
	III	0.00	0.02	14.6	8.84	30.15	1.90
	IV	0.00	0.03	15.3	3.25	32.28	0.88
	V	0.00	0.00	17.7	1.52	36.95	0.24
February	**I**	0.00	0.00	0.04	0.00	41.03	0.28
	II	0.00	0.00	0.00	0.00	42.67	0.37
	III	0.00	0.00	0.00	0.00	47.79	0.54
Average	**0.00**	**0.12**	**5.86**	**1.47**	**21.84**	**0.66**	
SD	0.00	0.21	5.81	2.30	16.07	0.63	

Note: SD: Standard deviation

Table 2. Moth catches of pink bollworm in pheromone traps installed in *Bt* cotton fields located in Vadodara and Kheda district during 2014 - 15 (Averaged over 9 fixed plots)

Month and week		Average number of pink bollworm moth catches/ trap/ week	
		Vadodara district	Kheda district
1		2	3
November	**III**	0.11	0.22
	IV	0.00	0.17
December	**I**	0.00	0.06
	II	0.78	1.44
	III	2.94	1.89
	IV	4.33	0.61
January	**I**	3.28	2.00
	II	1.33	1.33
	III	2.39	1.67
	IV	2.11	2.33
	V	2.39	1.28
February	**I**	2.00	2.00
	II	2.72	0.89
	III	1.61	1.61
Average	**1.86**	**1.25**	
SD	1.31	0.75	

Note: SD: Standard deviation

the mirid bug and pink bollworm are found as emerging inset pests of *Bt* cotton during 2014-2015.

The cotton mirid bug, *Creontiades biseratense* (Distant) is an emerging insect pest on *Bt* cotton in Karnataka, India causing heavy shedding of squares and bolls which lead to significant reduction in seed cotton yield (Patil *et al.*, 2006; Ravi, 2007 and Udikeri *et al.*, 2009). The pest has also been noticed in Tamil Nadu, Andhra Pradesh and Maharashtra (Surulivelu and Dhara jothi, 2007).

Crops genetically engineered to produce insecticidal proteins from the bacterium *Bacillus thuringiensis* (*Bt*) kill some key pests and reduce reliance on insecticide sprays. Such *Bt* crops were commercialized in 1996 and planted on more than 50 million hectares worldwide in 2009 (James, 2009). The major threat to the continued success of *Bt* crops is evolution of resistance by pests. While most target pest populations remain susceptible, resistance to *Bt* crops has been reported in one of the most devastating pests of cotton globally recently, the pink bollworm (*Pectinophora gossypiella* Saunders), evolved resistance to transgenic cotton that produces *Bt* toxin Cry1Ac in western India (Bagla, 2010). Thus, the pink bollworm had the genetic potential to evolve resistance and was under intense selection for resistance in the field. The pink bollworm said to be rampant through out Vadodara district especially in middle Gujarat.

Department of Agriculture and Co operation, Ministry of Agriculture, Government of India sponsored project "On-line Pest Monitoring and Advisory Services under commercial crops (OPMAS)" on ICT based e-pest surveillance and advisory and implemented by NCIPM, New Delhi in 2014-2015. The main object is to monitor the pests in cotton, issue the pest advisories timely to extension agencies and farmers, disseminate the IPM activities across the country.

For the purpose, the investigation was undertaken during cropping period in different *Bt* cotton growing districts *viz.*, Vadodara and Kheda. In each district, major cotton growing three talukas were selected and in each taluka, three villages were selected as per the guideline. During the course of study total 18 villages of both the districts were surveyed at weekly interval by field assistants allotted to each taluka for recording the insect pests observations and recorded pest data were uploaded on the NCIPM website. In the present investigation, pink bollworm and mirid bug were found as the emerging pests in *Bt* cotton. The observations

Table 3. Infestation of pink bollworm, *P. gossypiella* in *Bt* cotton in Vadodara district during 2014 - 2015 (Boll Destruction Method)

Taluka	Village	Field no.	No. of damaged bolls out of 30			Picking wise infestation of pink bollworm (%)			
			1st	2nd	3rd	1st	2nd	3rd	**Average**
Karjan	Kandari	F1	03	25	12	10.00	83.33	73.33	**55.55**
		F2	04	19	28	13.33	63.33	93.33	**56.66**
		R1	04	26	19	13.33	86.66	63.33	**54.44**
		R2	07	25	25	23.33	83.33	83.33	**63.33**
					Average	**15.00**	**79.16**	**78.33**	**57.50**
	Bamangam	F1	00	16	12	0	53.33	40.00	**31.11**
		F2	01	05	15	3.33	16.66	50.00	**23.33**
		R1	02	12	10	6.66	40.00	33.33	**26.66**
		R2	02	04	23	6.66	13.33	76.66	**32.22**
					Average	**4.16**	**30.83**	**50.00**	**28.33**
	Ganapatpura	F1	00	25	10	0	83.33	33.33	**38.89**
		F2	00	24	27	0	80.00	90.00	**56.67**
		R1	03	20	25	10.00	66.66	83.33	**53.33**
		R2	00	22	08	0	73.33	26.66	**33.33**
Dabhoi					**Average**	**2.50**	**75.83**	**58.33**	**45.55**
	Kuvarpura	F1	05	08	10	16.66	26.66	33.33	**25.55**
		F2	08	14	07	26.66	46.66	23.33	**32.22**
		R1	00	05	12	0	16.66	40.00	**18.89**
		R2	00	08	10	0	26.66	33.33	**20.00**
					Average	**10.83**	**29.16**	**32.50**	**24.16**
	Khanpura	F1	04	03	15	13.33	10.00	50.00	**24.44**
		F2	00	09	10	0	30.00	33.33	**21.11**
		R1	00	12	17	0	40.00	56.66	**32.22**
		R2	3	04	10	10.00	13.33	33.33	**18.89**
					Average	**5.83**	**23.33**	**43.33**	**24.17**
	Menpura	F1	00	06	05	0	20.00	16.66	**12.22**
		F2	2	04	15	6.66	13.33	50.00	**23.33**
		R1	00	03	15	0	10.00	50.00	**20.00**
		R2	00	10	10	0	33.33	33.33	**22.22**
					Average	**1.67**	**19.17**	**37.50**	**19.44**
Savli	Gulabpura	F1	00	05	05	0	16.66	16.66	**11.11**
		F2	00	07	09	0	23.33	30.00	**17.78**
		R1	00	01	10	0	3.33	33.33	**12.22**
		R2	02	06	06	6.66	20.00	20.00	**15.55**
					Average	**1.67**	**15.83**	**25.00**	**14.16**
	Ghothada	F1	00	07	09	0	23.33	30.00	**17.78**
		F2	02	06	04	6.66	20.00	13.33	**13.33**
		R1	00	03	08	0	10.00	26.66	**12.22**
		R2	00	01	04	0	3.33	13.33	**5.55**
					Average	**1.67**	**14.17**	**20.83**	**12.22**
	Anjesar	F1	00	03	03	0	10.00	10.00	**6.67**
		F2	01	02	10	3.33	6.66	33.33	**14.44**
		R1	01	03	07	3.33	10.00	23.33	**12.22**
		R2	00	04	06	0	13.33	20.00	**11.11**
					Average	**1.67**	**10.00**	**21.67**	**11.11**
					Average of district	**5.00**	**33.05**	**40.83**	**26.29**

Note: F: Fixed plot; R: Random plot; 1st picking: 04/12/2014; 2nd picking: 19/12/2014 and 3rd picking: 03/01/2015 on the activity of mirid bugs/plant were recorded at weekly interval from the 20 randomly selected plants from each plot. For recording incidence of pink bollworm, 20 plants were randomly selected from the each plot and from each selected plant toal number of healthy squares and green bolls and total number of damaged squares and green bolls were counted at weekly interval and per cent incidence was worked out.

The activity of mirid bug was observed during 2nd week of November, 2014 to 4th week of January, 2015 in Kheda district. The population of this pest was ranged from 0.03 to 0.81/plant under monitoring fields. In Vadodara district, the activity of this emerging pest was not observed.

The activity of pink bollworm was observed during 2nd week of November, 2014 to 3rd week of February, 2015. The infestation on square due to pink bollworm was observed in the range of 0.04 to 17.70 per cent and 0.09 to 8.84 per cent in Vadodara and Kheda district, respectively. The highest (17.70 %) infestation on square due to pink bollworm was observed during 5th week of January, 2015 in Vadodara district whereas in case of Kheda district, it was during 3rd week of January, 2015. The infestation on green bolls due to pink bollworm was observed in the range of 2.50 to 47.79 per cent and 0.05 to 1.90 per cent in Vadodara and Kheda district, respectively. The highest (47.79%) infestation on green bolls due to pink bollworm was observed during 3rd week of February, 2015 in Vadodara district whereas in case of Kheda district, it was during 3rd week of January, 2015. As far as catches of *P. gossypiella* in pheromone traps (Table 2) is concerned, it was started from 2nd week of November, 2014 to 3rd week of February, 2015 to the tune of 0.11 to 4.33 moths/trap/week and 0.06 to 2.33 moths/trap/week in Vadodara and Kheda district, respectively. The peak activity of the pest was recorded during 4th week of December, 2014 *i.e.* more than 4 moths per trap in Vadodara district.

The monitoring of pink bollworm resistance was also worked out. For the purpose, boll samples (30 bolls/plot/village) from each selected villages were collected at 90, 105 and 120 days after sowing (DAS) and brought to the laboratory and worked out the per cent incidence by "Boll Destruction Method". The incidence of pink bollworm was high in Vadodara district (upto 94%) irrespective of the *Bt* cotton varieties under studies. In Vadodara district, the highest pink bollworm population was recorded in Karjan taluka (45.55%) followed by Dabhoi (19.44 per cent). The least incidence of pink bollworm was recorded in Savli taluka (11.11%) (Table 3). In case of Kheda district, incidence of pink bollworm was lower (upto 27%) as compared to Vadodara district irrespective of the *Bt* cotton varieties under studies. In Kheda district, the highest pink bollworm population was recorded in Kathalal taluka (10.55%) followed by Thasra (5.83%). The least incidence of pink bollworm was recorded in Kapadwanj taluka (2.22%) (Table 4). On an average, incidence of pink bollworm in *Bt* cotton in Vadodara and Kheda district was 26.29 and 5.52 per cent, repectively. Comparatively lower incidence of pink bollworm was recorded in Kheda district than Vadodara district. This variation could be due to area under cotton, initiation of pest activity and general sowing pattern for which vadodara has an edge over Kheda distrcit.

The field survival of pink bollworm revealed the possibility of resistance build up and farmers must have to resort appropriate resistance management strategies to sustain the BG technology especially in the hot spot areas. The emerging and future insect pests problem have to be tackled with IPM approaches

Table 4. Infestation of pink bollworm, *P. gossypiella* in *Bt* cotton in Kheda district during 2014 - 2015 (Boll Destruction Method)

Taluka	Village	Field number	Number of damaged bolls out of 30			Picking wise infestation of pink bollworm (%)			
			1st	2nd	3rd	1st	2nd	3rd	**Average**
Kapadvanj		F1	00	01	02	0	0	6.66	**2.22**
	Kapadivav	F2	00	00	01	0	0	3.33	**1.11**
		R1	00	00	03	0	0	10.00	**3.33**
		R2	00	01	00	0	0	0	**0.00**
					Average	**0.00**	**0.00**	**5.00**	**1.67**
	Antisar	F1	00	01	01	0	0	3.33	**1.11**
		F2	00	02	00	20.00	3.33	0	**7.78**
		R1	06	00	00	16.66	0	0	**5.55**
		R2	05	02	00	0	3.33	0	**1.11**
					Average	**9.17**	**1.67**	**0.83**	**3.89**
	Thavad	F1	00	02	01	3.33	6.66	3.33	**4.44**
		F2	00	00	02	0	0	6.66	**2.22**
		R1	00	01	00	0	0	6.66	**2.22**
		R2	00	01	01	0	0	0	**0.00**
Kathalal					**Average**	**0.83**	**1.67**	**4.16**	**2.22**
	Sikandar porda	F1	05	00	06	16.66	0	13.33	**10.00**
		F2	00	01	03	0	3.33	10.00	**4.44**
		R1	03	04	01	10.00	13.33	3.33	**8.89**
		R2	09	02	00	30.00	6.66	0	**12.22**
					Average	**14.17**	**5.83**	**6.67**	**8.89**
	Vishwanath pura	F1	04	04	05	13.33	13.33	16.66	**14.44**
		F2	00	02	01	0	6.66	3.33	**3.33**
		R1	03	00	00	10.00	0	0	**3.33**
		R2	00	00	04	0	0	13.33	**4.44**
					Average	**5.83**	**5.00**	**8.33**	**6.39**
	Continue								
	Laxmipura	F1	00	02	01	0	6.66	3.33	**3.33**
		F2	06	01	05	20.00	3.33	16.66	**13.33**
		R1	02	00	08	6.66	0	26.66	**11.11**
		R2	03	04	06	10.00	13.33	20.00	**14.44**
					Average	**9.17**	**5.83**	**16.66**	**10.55**
Thasara	Labhapura	F1	00	02	03	0	6.66	10.00	**5.55**
		F2	00	01	01	0	3.33	3.33	**2.22**
		R1	00	03	05	0	10.00	16.66	**8.89**
		R2	00	00	01	0	0	3.33	**1.11**
					Average	**0.00**	**5.00**	**8.33**	**4.44**
	Ajupura	F1	00	05	02	0	16.66	6.66	**7.77**
		F2	00	02	05	0	6.66	16.66	**7.77**
		R1	00	01	02	0	3.33	6.66	**3.33**
		R2	04	00	00	13.33	0	0	**4.44**
					Average	**3.33**	**6.66**	**7.50**	**5.83**
	Mugatpura	F1	03	02	02	10	6.66	6.66	**7.77**
		F2	00	00	07	0	0	23.33	**7.78**
		R1	00	00	03	0	0	10.00	**3.33**
		R2	02	02	00	6.66	6.66	0	**4.44**
					Average	**4.17**	**3.33**	**10.00**	**5.83**
					Average of district	**5.18**	**3.88**	**7.49**	**5.52**

Note: F: Fixed plot; R: Random plot; 1st picking: 04/12/2014; 2nd picking: 19/12/2014 and 3rd picking: 03/01/2015 as a part of a sustainable crop production technology.

REFERENCES:

Bapla, P. 2010. *Science* **327:** 1439.

James, C. 2009. *ISAAA Briefs* **41** (ISAAA, Ithaca, New York, USA, 2009).

Patil, B. V.; Bheemanna, M.; Patil, S. B.; Udikeri, S. S. and Hosmani, A. 2006. *Insect Environ.*, **11**: 176-17.

Ravi, P. R. 2007. *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad (India).

Surulivelu, T. and Dhara Jothi, B. 2007. http://www.cicr.gov.in.

Udikeri, S. S.; Kranthi, K. R.; Patil, S. B.; Shaila, H. M.; Matti, P. V.; Guruprasad, G. S.; Hirekurabar, R. B. and Khadi, B. M. 2009b. Proceeding of National Symp. on *"Bt-cotton: Opportunities and Prospectus"*, CICR, Nagpur, November 17-19, p.150.

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A rapid process for preparation of bio enriched compost from cotton stalks

V. MAGESHWARAN, N. M ASHTAPUTRE, HAMID HASAN, D. MONGA, P. NALAYANI, S.K. SHUKLA AND P.G. PATIL

Central Institute for Research on Cotton Technology, Mumbai – 400019

E-mail: mageshbioiari@gmail.com

ABSTRACT : A rapid composting process was developed for the preparation of bio-enriched compost from cotton stalks. The cotton stalks were treated with microbial consortia to fasten the composting process. Large scale composting experiments with ten tonnes of chipped cotton stalks per trial were conducted at Nagpur, Maharashtra; Sirsa, Haryana and Coimbatore, Tamil Nadu during 2011 and 2013. The raw cotton stalks used for composting at Nagpur and Coimbatore regions were dried (< 15% moisture) while at Sirsa, the stalks were wet (> 30% moisture). There were two treatments viz., microbial consortia treated and untreated (control). In each treatment, three heaps of 1.7 tonnes each were made. After thirty days of initiation (DAI) of composting process (cooling phase), the treated compost was enriched with plant growth promoting microorganisms. The results showed the carbon: nitrogen (CN) ratio was reached near to 20 at 60 and 45 DAI of composting in dry and wet cotton stalks respectively while, in control (untreated), the compost was ready at 90 and 60 DAI of composting. Thus, 30 and 15 days could be saved by using microbial consortia for the preparation of bio-enriched compost from dry and wet cotton stalks respectively. The NPK content of bio-enriched compost was about three times higher than farmyard manure. Thus, the preparation of bio-enriched compost from cotton stalks would be a viable solution for *in situ* management of cotton stalks for increasing soil fertility.

Key words : CN ratio, composting, cotton stalks, microbial consortia, nitrogen, phosphorus, potassium

In India about 30 million tonnes of cotton stalks are generated every year (Hiloidhari *et al.,* 2014). Cotton stalks comprise about 75-82 per cent holocellulose, 24-26 per cent lignin, 12-14 per cent moisture and 6-8 per cent ether extractive. Harvested stalks stored in the field serve as storehouse for harmful insects and diseases. Sometimes cotton stalks are mulched in the soil that requires heavy machinery & some additional fertilizer need to be added to enhance the stalk decaying process, which further involves high energy and cost. Most of the cotton stalks are treated as waste, some are being used as fuel by rural population, while annually, and the bulk of the cotton stalk is burnt after harvest to clean the field, which then leads to nutrient losses and increased CO_2 inputs to the atmosphere. Hence the best way to bring back the nutrient into the soil is composting of cotton stalks.

Composting is the process in which complex molecules such as lignin, cellulose, hemicelluloses, lipids is converted into simpler molecules (Nagarajan *et al.,* 1985 and Summerel and Berges, 1989). During the composting process, besides the final product in the form of humus; heat, compounds of nitrogen, oxygen, phosphorus, CO_2, H_2O, and a significant amount of microbial biomass is created (Tiquia *et al.,*2002). Many factors like temperature, moisture content, oxygen concentration and nutrient availability affects the rate of decomposition of organic matter. These factors, in turn, strongly affect the structure and diversity of the microbial community, microbial activities and the physical and chemical characteristics of the compost (Miller, 1993). Although considerable work has been done on composting of organic waste, composting of high lignin content organic material like cotton stalks within shorter period of time is still a challenge.

The moisture content of cotton stalks immediately after uprooting was 40 – 50 per cent and same was found drop from 50 to below 20 per cent when the stalks were left in the field, after uprooting for three weeks (Gemtos and Tsiricoglou, 1999). The cotton stalks are normally uprooted in central and southern parts of country when the plant is almost dry and the chipping of the uprooted dry cotton stalks left with a moisture of around 12 per cent (Anonymous, 2010). Hence, the response of these raw cotton stalks with varied moisture content towards composting in not yet known. Considering this, the present paper was aimed to study the influence of microbial consortia on preparation of bioenriched compost from wet and dry cotton stalks within shorter period and to characterize the prepared compost at different intervals.

MATERIALS AND METHODS

Microbial consortia : Microbial consortia consisted of aerobic consortium, anaerobic consortium and plant growth promoting microbes. The liquid aerobic and anaerobic microbial consortia were obtained from Microbiology lab, Central Institute for Research on Cotton Technology (CIRCOT), Mumbai. The microbial strains viz., *Bacillus stearothermophilus, Pleurotus flabellatus and Phanerochaete chrysosporium* were used for the preparation of aerobic consortium. The anaerobic consortium consisted of mixture of anaerobic and facultative anaerobic microbes. The commercial solid formulations of plant growth promoting microorganism's *viz., Azosprillum, Azotobacter, Fluorescent Pseudomonas, Phospobacteria and Trichoderma viridie* were obtained from IARI, New Delhi.

Cotton stalks : The cotton stalks were collected at Nagpur, Maharashtra; Sirsa, Haryana and Coimbatore, Tamil Nadu. The chipped cotton stalks of 3 to 4 cm length and 1 to 2 cm thickness were used for composting purpose. The chipped cotton stalks collected from Sirsa was termed as wet cotton stalks since the initial moisture recorded was 30-35 per cent while cotton stalks collected from Nagpur and Coimbatore were termed as dry cotton stalks since the moisture content recorded was 10 – 15 per cent.

Composting trial : The large scale trials on composting of cotton stalks using ten tonnes of chipped cotton stalks were conducted at CIRCOT unit at Nagpur, CIRCOT unit at Sirsa and Central Institute for Cotton Research (CICR) unit at Coimbatore respectively. There were six experiments conducted with two trials at each centre. The month and year of composting experiments carried out is indicated in Table 1. In each experiment, six heaps were made of 1.7 tonnes each. Three heaps were kept as control (without microbial consortia) and remaining three heaps were kept as treated (with microbial consortia). The ingredients *viz.,* alkali (0.2%), cattle dung (10%), garden soil (0.1), Urea (1.2%), Diammonium phosphate (2%), aerobic and anaerobic culture (0.1%) each in treated heaps only) were added and mixed in sequential manner and heaps were made. The initial moisture content maintained was 50 per cent including the moisture content of raw cotton stalks. The individual heaps were covered with polythene sheets. At 30th day of composting, the plant growth promoting microorganisms (*Azosprillum, Azotobacter, Fluorescent Pseudomonas, Phospobacteria and Trichoderma viridie*) were added each @ 0.1% in the treated heap only. All the heaps were turned periodically for every week for proper aeration.

Table 1. Details of composting experiments

S. No.	Place	Month	Year
1.	CIRCOT unit, Nagpur	June - August	Trial I (2011), Trial II (2012)
2.	CIRCOT unit, Sirsa	January - March	Trial I (2012), Trial II (2013)
3.	CICR unit, Coimbatore	June - August	Trial I (2011), Trial II (2013)

Analysis of compost samples : The samples were taken from each heap at periodic intervals at 0, 15, 30, 45, 60 and 90 days of composting, oven dried and powdered. The powdered samples were passed through 200 μ size sieve and used for analysis. Each sample was analyzed for organic carbon (Walkey and Black, 1934), Total N by micro-Kjeldhal (Humphires, 1956), Total P (Jackson, 1973), Total K by Flame photometer (Stanford and English, 1949) and Cellulose, Hemicellulose and Lignin (Van Soest, 1963). CN ratio was determined by finding out ratio between total organic carbon and total nitrogen.

The fresh samples taken during different intervals were used for analyzing pH, enzyme activity and total microbial count. The pH was measured using pH meter. The cellulase activity was determined according to Benefield, 1971. The urease activity was measured by following the method of Tabatabai and Bremner, 1972. The unit of cellulase activity was expressed in mg of glucose released/g of sample / h while urease activity was expressed in mg of ammonium N released /g of sample / h. The total microbial count including total bacterial, total fungi and total actinomycetes counts were determined using 1g of wet sample by standard serial dilution technique.

RESULTS AND DISCUSSION

Use of organic wastes in agriculture is known to reduce the pollution and improve soil quality. An attempt was made in the present study to utilize the cotton stalks, an organic waste, which is locally available in large quantities after harvesting and having the disposal problem in major cotton growing states of India. Farmers are burning the stalks obtained after harvesting as they take more time for biodegradation due to its high lignin content and broad C: N ratio. At present, the cotton stalks are mostly burnt and sometimes used as domestic fuel. Hence, an attempt was made to accelerate the process of composting of cotton stalks using efficient lignin degrading microbes and enrich the compost with plant growth promoting microorganisms.

The microbial consortia include aerobic consortium, anaerobic consortium and plant growth promoting microorganisms. The trial was taken for ten tonnes of chipped cotton stalks and the compost samples were analyzed for various properties. The results on compost prepared from wet cotton stalks were reported based on the consolidation of trial results taken at Sirsa. The results on compost prepared from dry cotton stalks were reported based on the consolidation of trial results taken at Nagpur and Coimbatore.

During the composting process, there was an increase in temperature in compost heaps was recorded from 10 - 15 DAI and the trend was prolonged up to 30 to 35 DAI. The maximum temperature recorded in the compost heaps during the thermophilic phase was 55 - 60°C (data not shown). The mineralization occurs most rapidly during the thermophilic phase of composting (40 – 60° C) which lasts for several weeks or months depending on size of the system and composition of the ingredients. High temperature (60-75°C) reached in thermophilic phase of composting is a factor which completely reduces the number of pathogens (Macgregor *et al.,* 1981).

CN ratio : CN ratio is an important indicator for composting process. As per Fertilizer Control Order (FCO), Government of India, 1985 (FAI, 2007), the CN ratio should reach below 20 to indicate the process of completion of composting. In the present study, the changes in CN ratio for wet and dry cotton stalks during different intervals were evaluated. The composting experiments conducted using wet cotton stalks at Sirsa during the period 2011 and 2012 showed that the CN ratio of treated wet cotton stalks reached to 20.0 at 45 DAI while untreated wet cotton stalks reached to 20.0 at 60 DAI (Fig. 1). Thus, the results indicated that the treatment of cotton stalks with microbial consortia could reduce the time period of preparation of compost from wet cotton stalks by fifteen days. Similarly, the composting experiments conducted during 2011 and 2013 using dry cotton stalks at Coimbatore and Nagpur suggested that CN ratio reached to 20.0 at 60 DAI in treated and 90 DAI in untreated compost respectively. The results showed the treatment of microbial consortia reduce the time period of preparation of compost from dry cotton stalks by thirty days. CN ratio is an important indicator for composting process. Several workers have suggested that inoculation of fungal cultures resulted in rapid decomposition of agro-residues with decreases in CN ratio (Jagadeesh *et al.,* 1996 and Singh *et al.*, 1992).

In this study, to accelerate the composting process, mixture of lignocelluloytic microorganisms including *P. chrysosporium*, *B. stearothermophilus* and *P. flabellatus* was used. In a similar study, the inoculation of lignocellulolytic microorganisms such as *P. sajor-caju*, *T. harzianum*, *A. niger* and *Azotobacter chrococcum* to enhance the composting process was reported for wheat straw composting (Singh and Sharma, 2002). The composted cotton stalks had significantly reduced hemicelluloses and lignin than cellulose when compared to raw cotton stalks (results not shown). The observed results might be due to more susceptibility of hemicelluloses towards microbial degradation than other counterparts. During the degradation, part of lignin is also degraded which results in decrease in lignin content. Similar results were found by Kadalli, 1999 and Nagarajan *et al.*, 1985. The fungal pretreatment of cotton stalks by *P. chrysosporium* showed significant lignin and hemicelluloses degradation compared to untreated stalks (Shi *et al.,* 2009). The lignocellulosic degradation during composting process was due to composite cultures than single organism in which each organism have different specificity and thus brings faster decomposition (Arora and Garg, 1992 and Gupta *et al.,* 2004).

Biological characterization : The samples taken during different intervals of composting were analysed for biological characteristics such as enzyme activity and total microbial count. The enzyme activities such as

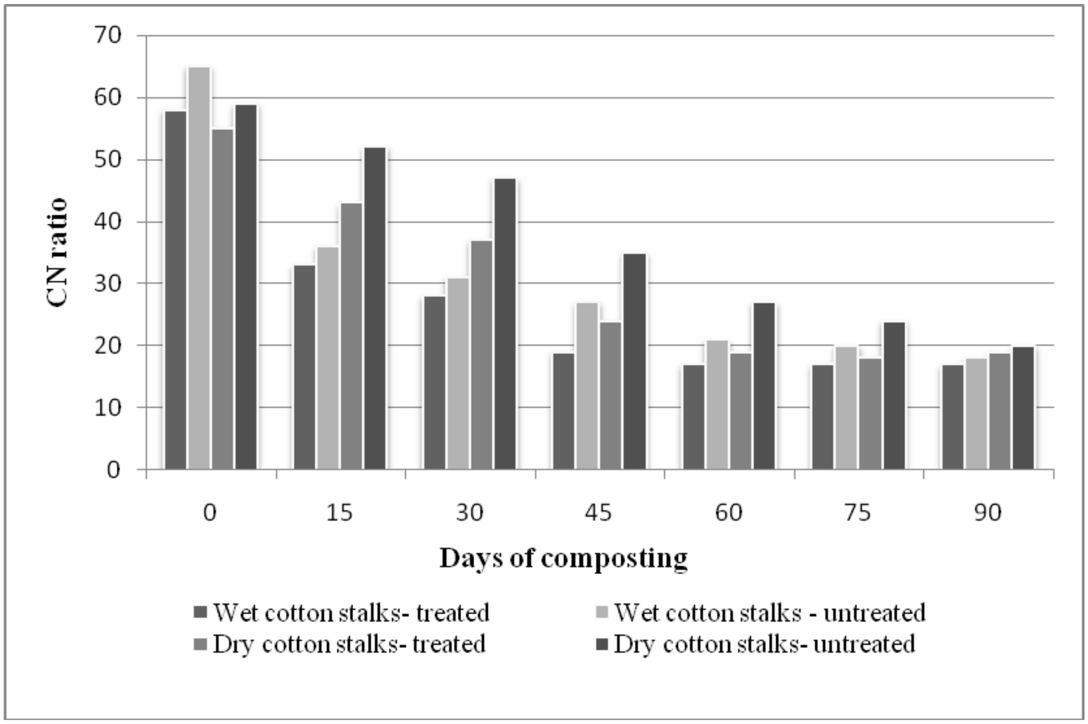


Fig. 1. CN ratio of compost prepared from cotton stalks during different intervals

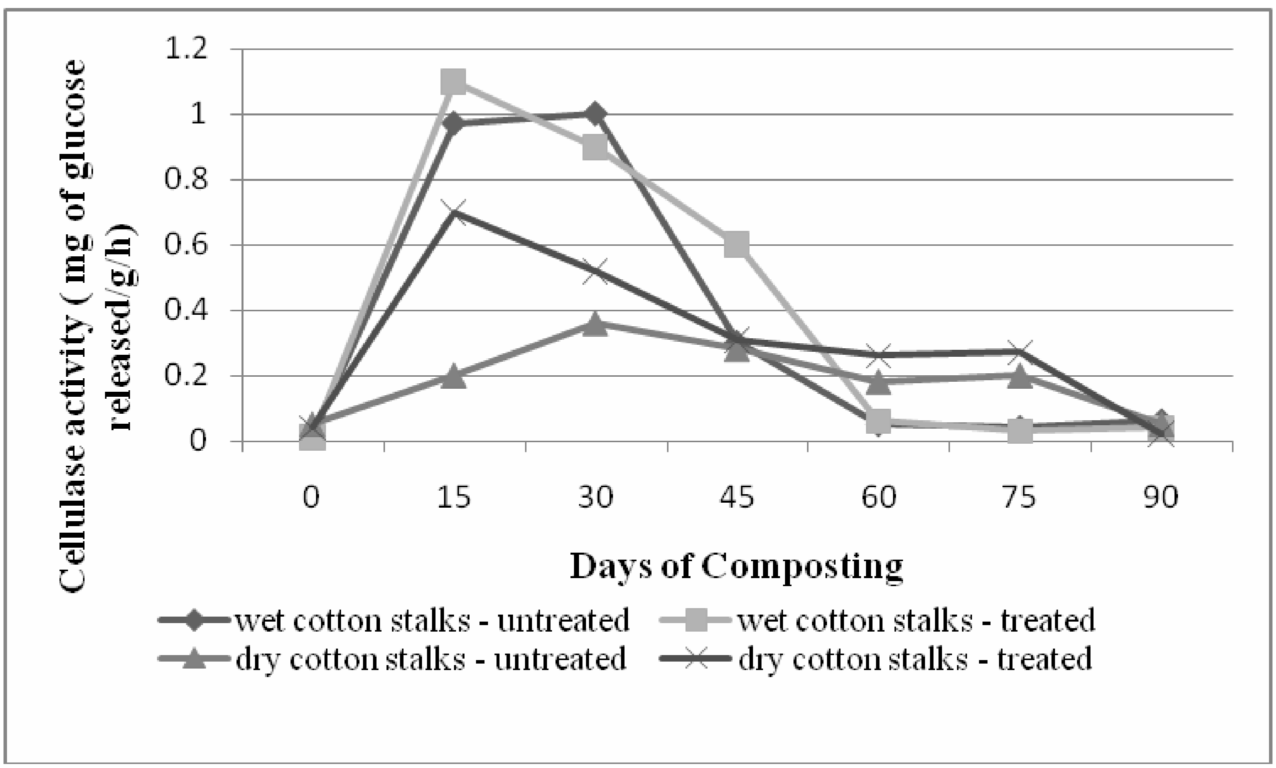


Fig. 2. Cellulase activity of compost prepared from cotton stalks during different intervals

Table 2 Total microbial count of compost prepared from cotton stalks during different intervals

Treatments	DAI of composting											
	Total bacterial count (cfu x 10^9)				Total fungi count (cfu x 10^5)				Total actinomycetes count (cfu x 10^7)			
	0	30	60	90	0	30	60	90	0	30	60	90
Wet cotton stalks- untreated	1.0^{c}	2.6^{b}	3.3^{b}	4.1^{a}	3.5^{b}	4.4^{ab}	2.4^{b}	1.7^{c}	$4\ .0^{b}$	20.0^{b}	36.0^{*}	30.0^{*}
Wet cotton stalks - treated	2.8^{b}	45.0^{a}	4.0^{b}	5.2^{a}	110.0^{a}	4.8^{a}	3.9^{b}	2.4^{bc}	9.7^{b}	28.0^{ab}	48.0^{*}	38.0^{*}
Dry cotton stalks - untreated	2.7^{b}	3.8^{b}	31.0^{a}	4.5^{a}	2.8^{b}	1.5^{c}	11.0^{ab}	3.6^{b}	9.6^{b}	17.0^{b}	36.0^{*}	47.0^{*}
Dry cotton stalks - treated	8.0^{a}	32.0^{a}	48.0^{a}	12.0^{b}	130.0^{a}	3.2^{b}	19.0^{a}	5.7^{a}	20.0^{a}	37.0^{a}	45.0^{*}	50.0^{*}

DAI: Days after initiation; * Non Significant; Treatment values followed by same alphabet do not differ significantly. There were three replications per treatment. The values are the means of two different experiments.

cellulase and urease activity were studied. The cellulase activity (mg of glucose released/g/h) was found to be higher in 15 days after initiation (DAI) of composting in the microbial consortia treated cotton stalks (Fig. 2). The cellulase activity recorded was 1.1 and 0.7 in treated wet and dry cotton stalks respectively while in the untreated cotton stalks, the cellulase activity was higher during 30^{th} DAI. The cellulase activity recorded in untreated wet and dry cotton stalks was 1.0 and 0.4, respectively. The cellulase activity was recorded higher during the initial stages of composting process and drastically reduced after 60^{th} DAI. In a similar study, Semenov *et al.,* 1995 reported that cellulase activity was increased with increase in temperature. The urease activity (mg of ammonium N released/ g/h) was found to be 0.08 at 0^{th} DAI in dry and wet cotton stalks in treated as well as untreated. During the remaining period of composting, the urease activity was found in the range of 0.02 to 0.04 and there was no difference in the activity among treated and untreated cotton stalks was observed (results not shown).

The total microbial count including bacteria, fungi and actinomycetes were estimated in compost at different intervals (0,

Table 3. Physico chemical characterization of compost prepared from wet cotton stalks during different intervals

DAI of composting		Physico chemical characters				
		pH	Organic carbon (%)	Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)
0	UT	8.0^{a}	38.0^{a}	0.6^{b}	0.2^{e}	0.2^{g}
	T	7.8^{a}	33.0^{b}	0.6^{b}	0.2^{e}	0.3^{fg}
45	UT	7.3^{b}	28.0^{c}	1.0^{a}	0.6^{d}	0.5^{ef}
	T	7.1^{b}	22.2^{d}	1.1^{a}	0.9^{bc}	0.8^{bcd}
60	UT	7.1^{b}	21.0^{d}	1.0^{a}	0.8^{cd}	0.6^{de}
	T	7.1^{b}	20.4^{d}	1.1^{a}	1.1^{ab}	0.9^{abc}
75	UT	7.2^{b}	20.0^{d}	1.0^{a}	0.9^{b}	0.7^{cde}
	T	7.2^{b}	18.5^{d}	1.1^{a}	1.2^{a}	0.9^{abc}
90	UT	7.1^{b}	20.0^{d}	1.1^{a}	0.9^{bc}	1.0^{ab}
	T	7.2^{b}	19.4^{d}	1.2^{a}	1.2^{a}	1.1^{a}

DAI: Days after initiation; UT: Untreated; T: Treated Treatment values followed by same alphabet do not differ significantly. There were three replications per treatment. The values are the means of two different experiments.

Table 4 Physico-chemical characterization of compost prepared from dry cotton stalks during different intervals

DAI of composting		Physico chemical characters				
		pH	Organic carbon (%)	Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)
0	UT	8.0[a]	35.0*	0.6[d]	0.2[e]	0.8[c]
	T	7.8[ab]	33.0*	0.6[d]	0.2[e]	0.9[c]
45	UT	7.5[bc]	35.0*	1.0[cd]	0.3[de]	1.1[bc]
	T	7.1[c]	30.0*	1.2[bc]	0.5[cd]	1.1[bc]
60	UT	7.0[de]	35.0*	1.3[bc]	0.3[de]	1.3[abc]
	T	7.3[cd]	30.0*	1.6[ab]	0.8[ab]	1.5[ab]
75	UT	6.7[e]	34.0*	1.4[abc]	0.5[cd]	1.3[abc]
	T	6.9[e]	32.0*	1.8[a]	1.0[a]	1.8[a]
90	UT	6.8[e]	33.0*	1.6[ab]	0.6[bc]	1.5[ab]
	T	6.8[e]	34.0*	1.8[a]	0.9[a]	1.8[a]

DAI: Days after initiation; UT: Untreated; T: Treated; * Non Significant; Treatment values followed by same alphabet do not differ significantly. There were three replications per treatment. The values are the means of two different experiments.

15, 30, 45, 60 and 90 DAI). The enumerated microbial count at 0, 30, 60 and 90 DAI is presented in Table 2. The total bacterial count was found higher in compost prepared from treated wet and dry cotton stalks at 30th DAI and 60th DAI respectively. The respective values were 45× 10^9 cfu/g and 48× 10^9 cfu/g. The total fungal count was higher at 0th DAI in both the wet and dry cotton stalks treated samples and their respective counts were 110 × 10^5 cfu/g and 130 × 10^5 cfu/g. The total actinomycetes population was higher during the later stage of composting (60th and 90th DAI). The actinomycetes population during this period did not differ significantly among the treatments. Among the microbial populations, bacterial population dominated all stages of decomposition process followed by actinomycetes and fungi. The similar results were obtained by Nodar *et al.,* 1990. It was obvious that increase in microbial population in treated compost than untreated was due to addition of microbial consortia including plant growth promoting microorganisms in the treated compost.

Physico chemical characterization : The physico-chemical properties of compost prepared from wet and dry cotton stalks are presented in Table 3 and Table 4, respectively. The initial pH of the compost at 0th DAI was slightly alkaline 8.0 ± 0.2. After 45th DAI, the pH of the compost was in the range of 7.0 ± 0.5. At 0th DAI of composting, the organic carbon (OC) content (%) was in the range of 33 to 38% (Table 3 and 4). The OC (%) content was reduced from 30 to 20 and 33 to 19.4 in untreated and treated wet cotton stalks compost respectively (Table 3) while the OC was unchanged in dry cotton stalks composting which needs further investigation (Table 4). The results are in accordance with the observations of Gupta *et al.,* 2004; Imam and Sharanappa, 2002 who also reported decrease in the organic carbon when different crop residues was composted with poultry manure. In a similar study, the treatment of cotton stalks with *P. chrysosporium* and *Azotobacter* resulted in decrease in OC (%) from 43.9 to 30.65 and increase in TN (%) from 1.46 to 2.16 was observed over the period of 16 weeks (Seoudi, 2013). The total nitrogen (%) (TN), total phosphorus (%) (TP) and total potassium (%) (TK) was recorded higher in treated cotton stalks than untreated cotton stalks. As stated earlier (Fig. 1), the CN ratio was reached to 20 at 45 DAI and 60 DAI in microbial consortia treated wet and dry cotton stalks respectively. Similarly, significant increase in TN, TP and TK contents were observed at 45 DAI and 60 DAI in microbial consortia treated wet and dry cotton stalks respectively. The TN, TP, TK contents recorded in treated wet cotton stalks compost at 45 DAI and 90 DAI of composting were 1.1, 0.9 0.8 and 1.2, 1.2, 1.1 respectively (Table 3). The TN, TP, TK contents was higher in compost prepared from dry cotton stalks than wet cotton stalks. The TN, TP, TK contents recorded in treated dry cotton stalks compost at 60 DAI and 90 DAI of composting were 1.6, 0.8, 1.5 and 1.8, 0.9, 1.8, respectively.

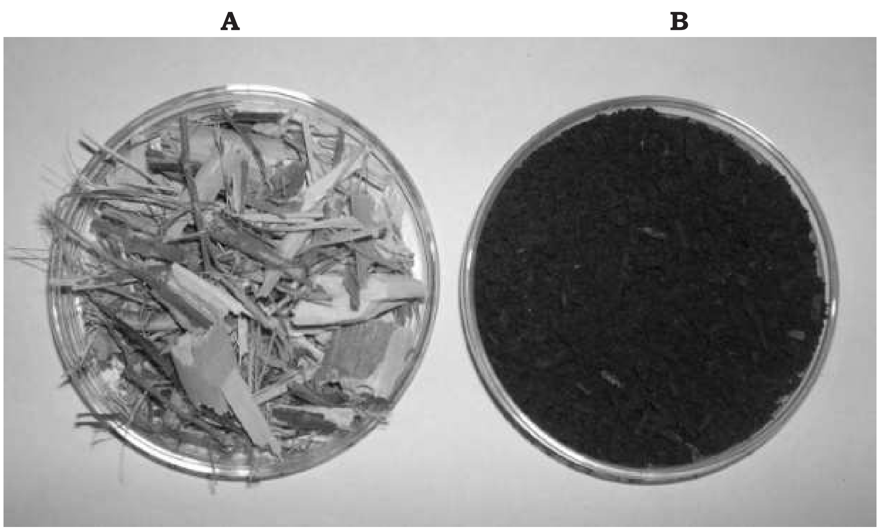


Fig. 3. Bio-enriched compost from cotton stalks
(A- raw cotton stalks; B- bio-enriched cotton stalks compost)

The increase in nitrogen content during composting might be a direct manifestation of mass carbon loss (Nagarajan *et al.*, 1985; Maleena, 1998; Singh *et al.*, 1992). Similar results were obtained by Gaur and Singh, 1982 that there was 27 per cent increase in nitrogen content, when mechanized compost inoculated with *Azotobacter* and rock phosphate. It is also evident from the experiments of Kapoor et al., 1983 that *Azotobacter* inoculation helps in increasing the N content of compost. It has also been reported by Kavitha and Subramanian, 2007 that the phosphorus content was increased conspicuously with addition of composted poultry litter, rock phosphate and microbial inoculants. The FCO recommends that the TN, TP and TK content (%) in the compost should be 1.0, 0.8 and 0.8 respectively and colour of the compost should be dark brown to black (FAI, 2007). Our results were in accordance with FCO where the colour of the compost was completely turned to black. The matured bio-enriched compost prepared from wet cotton stalks is presented in the Fig. 3. Thus these results indicated that physico-chemical properties of the microbial consortia treated compost prepared from wet and dry cotton stalks at 45 DAI and 60 DAI respectively meets the quality standards as prescribed by FCO. The TN, TP, TK content (%) of farm yard manure (FYM) was calculated to be 0.5, 0.2, 0.5 respectively (results not shown). It was noted that the TN, TP, TK level of bio-enriched compost prepared from dry cotton stalks in this study was about three times higher than FYM.

CONCLUSION

In the present paper, the effect of microbial consortia on rapid composting and nutrient level improvement in wet and dry cotton stalks were studied. The results showed that, good quality compost was prepared at 45 and 60 days from wet and dry cotton stalks using microbial consortia, while the same was obtained at 60 and 90 days respectively without microbial consortia. Thus fifteen and thirty days could be saved for the preparation of compost from wet and dry cotton stalks respectively. The results also showed that the nutrient level of microbial treated compost is better than untreated compost. Thus the process developed will not only yield good quality compost but also a viable on-farm solution for effective management of cotton stalks. In future, experiments may be conducted for mechanization of this process for large scale preparation of compost from cotton stalks at farm level.

REFERENCES

Anonymous, 2010. Utilization of cotton plant by-produce for value-added products. Final Report of Project. Common Fund for Commodities (CFC)/ICAC/20.

Arora, D.S. and Garg, K.K. 1992. Comparative degradation of lignocellulosic residues by different fungi. *Bioresource Technology*, **1**: 279-80.

Benefield, C.B. 1971. A rapid method for measuringcellulase activity in soil. *Soil Biol. Biochem.* **3** : 325-29.

FAI, 2007. The Fertilizer (Control) Order. 1985. The Fertilizer Association of India, 10, Saheed Jit Singh Marg, New Delhi, India.

Gaur, A.C. and G. Singh. 1982. Influences of Azotobacter and Rock phosphate on Enriching Mechanized Compost. In: Recycling of crop, animal and industrial waste in agriculture. Tandon HLS (Ed.): 12.

Gemtos, T.A and Tsiricoglou, Th. 1999. Harvesting of cotton residue for energy production. *Biomass and Bioenergy*, **16**: 51-99.

Gupta, S.B., Tamraka, D.K., Tamrakar, M.P., Thakur, K., Tedia, A. T. and Keshry, P.K. 2004. Effect of crop beneficial microbes on decomposition rate of different crop residues. *Journal Soil Crop*, **14** : 1-4.

Hiloidhari, M., Das, D. and Baruah, D.C. 2014. Bioenergy potential from crop residue biomass in India. *Renewable Sustain Energy Rev.* **32**: 504-12.

Humphires, E.C. 1956. Mineral composition and ash analysis. In: Modern methods of plant analysis vol I (eds.,) K. Peach and M.V. Tracy Springer verlag, Berlin, pp. 468 –502.

Imam, A.K. and Sharanappa 2002. Growth and productivity of maize (*Zea mays* L.) as influenced by poultry waste composts and fertilizer levels. *Mysore Jour. Agri. Sci.*, **36 :** 203-07.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India private limited, New Delhi. 498.

Jagadeesh, K.S. and Geeta, G.S. 1994. Extracellular enzyme production by white rot fungi on different agro wastes, *Proceedings of National Conference on Fungal Biotechnology, Barkatullah University*, Bhopal, 19.

Kadalli, G.G. 1999. Coir dust based enriched composts and characterization of the humic fractions, *Ph.D. Thesis*, University of Agricultural Sciences, Bangalore.

Kapoor, K.K., Yadav, K.S., Singh, D.P., Mishra, M.M. and Tauro, P. 1983. Enrichment of compost by *Azotobacter* and phosphate solubilising microorganisms. *Agric. Wastes*, **5**: 125-33.

Kavitha, R. and Subramanian, P. 2007. Bioactive Compost – A value Added Compost with Microbial Inoculants and Organic Additives, *Jour.App. Sci.*, **7** : 2514-18.

Macgregor, S.T., Miller, F.C., Psarianos, K.M. and Finstein, M.S. 1981. Composting process control based on interaction between microbial heat output and temperature. *Appl. Environ. Microbiol.* **41** : 1321-30.

Maleena, I. 1998. Composting piggery waste: a review. *Bioresource Technol.* **63:** 197-203.

Miller, F.C.1993. In: Soil Microbiology (F.B.Metting, ed.), pp. 515-543.Marcel Dekker, New York.

Nagarajan, R., Manicham, T.S. and Kothandaraman, G.V. 1985. Manuarial value of coir pith. *Madras Agri. Jour.,* **72 :** 533-35

Nodar, R., Acea, M.J. and Carballas, T.N. 1990. Microbial population of poultry pine raw dust litter. *Biological Wastes*, **33:** 295-306.

Semenov, A.M., Nizovtseva, D.V. and Ranikov, N.S. 1995. Influence of temperature and supply of mineral nutrients on cellulase activity and micromycete development in samples of peat from a raised bog. *Microbiol.* **64** : 79-84.

Seoudi, O.A-T. 2013. Enhancement of cotton stalks composting with certain microbial inoculations. *J. Adv. Lab. Res. Biol.* **4**:26–35.

Shi, J., Sharma-Shivappa, R.R., Chinn, M and Howell, N. 2009. Effect of microbial pretreatment on enzymatic hydrolysis and fermentation of cotton stalks for ethanol production. *Biomass Bioenergy*. **33**: 88-96.

Singh, A and Sharma, S. 2002. Composting of a crop residue through treatment with microorganisms and subsequent vermicomposting. *Bioresource Technology*. **85** : 107-111.

Singh, S., Mishra, M.M., Goyal, S. and Kapoor, K.K. 1992. Preparation of nitrogen and phosphorous enriched compost and its effects on wheat (*Triticum aestivum*). *Indian J Agri. Sci.* **62**: 810-14.

Stanford, S and L. English. 1949. Use of flame photometer in rapid soil tests for potassium and calcium. *Agron. J.*, **41**: 446 – 47.

Summerel, B.A. and Berges, L. W. 1989. Decomposition and chemical composition of Cereal Straw. *Soil Biol. Biochem.* **21** : 551-59.

Tabatabai, M.A and Bremner, J.M. 1972. Assay of urease activity in soils. *Soil Biol Biochem.* **4**: 479–87.

Tiquia, S.M., Wan J.H.C. and Tam N.F.Y. 2002. Dynamice of yard trimmings as determined by *Waste and Recourses Action Program* (WRAP), Oxon.

Van Soest, P.J. 1963. Use of detergents in the anlaysis of fibrous feeds II. A rapid method for the determination of fibre and lignin. *J. Assoc. Offic. Agr. Chem.* **46**: 829-35.

Walkey, A and Black, I.A. 1934. Chromic acid titration method for determination of soil organic matter. *Soil Sci.* **63** : 251.

Enhancement of UV protective property of cotton fabric by using plant extract

VANDANA GUPTA AND NIRMAL YADAV
Textile and Apparel Designing Department, CCS Haryana Agricultural University, Hisar - 125004
E-mail: vandana.g178@gmail.com

ABSTRACT : The present study have been conducted to enhance the UV protective property of cotton fabric and to assess its acceptability by consumers. *Syzygium cumini* (jamun) plant was selected for this study and phytochemical analysis was conducted. Methanolic leaves extract of *Syzygium cumini* was prepared with soxhlet extraction method. The cotton fabric was treated with *Syzygium cumini* leaves extract by using pad-dry-cure process and was evaluated for ultraviolet protection factor (UPF). Results of phytochemical analysis revealed the presence of tannin, flavonoids, phenols which possess good UV absorbing properties as reported in review. The cotton fabric when treated with *Syzygium cumini* leaves extract exhibited 29.5 UPF value, providing very good protection as compared to untreated cotton fabric which exhibited 10.9 UPF value, providing poor protection. The results of the acceptability of developed cotton fabric revealed; majority of the respondents, preferred the developed cotton fabric with and without surface enrichment, for female garments followed by male and children garments. It was concluded that by improving UV protective property of cotton fabric using natural source such as plants can provide safe and healthy life for each member of the society and can increase the value and demand of cotton based textiles.

Keywords: Cotton fabric, syzygium cumini, phytochemical analysis, UV protection

Cotton fiber is amazingly versatile, whether alone or blended, it out shells all other fibers combined. Consumers know that fabrics made from cotton put forth natural comfort, visual appeal, durability and value. With the mercury scorching up in summer time, people prefer to hide behind cotton fabric due to its inherent properties like good absorbency, ecofriendly nature, lightweight and many more. According to the *Lifestyle and Retail Monitor*™ Survey, more than 9 in 10 (almost 100 percent) consumers state that they would like to choose cotton over synthetic active wear if cotton could wick moisture, regulate temperature, be lightweight, hold or lock color, resist UV rays (Cotton Incorporated Lifestyle Monitor, 2015). Due to depletion of ozone layer and high exposure to UV rays, problems such as sunburn, premature skin ageing, skin cancer and eye disorders are increasing (Holme, 2003). Clothing provides one of the most convenient forms of protection against UVR but not all type of garments provides sufficient sun protection. (http:www.arpansa.gov.au/services.unf/index.gfm). Studies reveal that favourite fibers like cotton, rayon, flax are the poorest UV absorbers, as compared to polyester, wool, silk and nylon (Crews *et al.*, 1999). Chemicals, currently used to impart ultraviolet radiation protection property to textile materials, are titanium di-oxide, zinc oxide along with the organic ultraviolet radiation absorbers such as phenylbenzotriazole and dibenzoylmethanes (Subtamaniyan *et al.*, 2013). Many such chemicals commonly used have not been established safe for long term human use.

Plant extracts and their active metabolites possess several types of activities such as antibacterial, antifungal, antioxidant, antiviral, etc. *Syzygium cumini* is one of the most important medicinal plant belonging to Myrtaceae family and is commonly known as jamun. In the traditional medicine systems, different parts such as seeds, leaves of *Syzygium cumini* have been used as liver tonic, to strengthen teeth and gums, diabeties, treat leucorrhoea, stomachalgia, fever (Soni *et al.,* 2011). Maske *et al.,* 2012 in their study, reported *Syzygium cumini* as an effective sunscreen agent for protection of skin from harmful ultraviolet radiations. Recognizing the importance of cotton in our life and consumer requirements for healthy life, this study have been conducted to develop UV protective fabric by using a natural source (*Syzgium cumini)* which has not been explored till date for its UV protective property on cotton fabrics.

MATERIALS AND METHODS

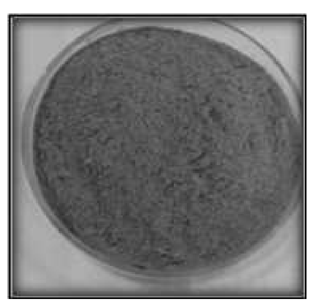
Material used : Fresh and mature leaves of *Syzygium cumini* (jamun) were collected from CCS, Haryana Agricultural University, Hisar. Various chemicals/auxiliaries such as methanol (solvent), Americos Amylase 543 (desizing agent), Palkascour (scouring agent), Fixa prêt Eco (resin cross linking agent), Magnesium chloride (catalyst) and 100 per cent plain woven cotton fabric were procured from the respective industries and the preliminary data of the procured fabric is presented in Table 1.

Table 1. Preliminary data of cotton fabric

Parameters Fabrics	Fabric count (ends and picks/ sq. inch)		Fabric thickness (mm)	Fabric weight (gm/m^2)
	Warp	Weft		
Woven	95	76	0.233	119

Preperation of *Syzygium cumini* leaves extract : 40gms of fresh and mature leaves of *Syzygium cumini* (jamun) were collected, washed and shade dried. The dried leaves were grounded in powder form and subjected to hot methanolic extraction at 55-60^0 C by using soxhlet extraction process, as described by Choudhary *et al.,* 2012 with slight modification.

Table 2. Steps followed for preperation of Syzygium cumini leaves extract

Plant	Fresh leaves	Dry leaves	Powdered leaves	Soxhlet extraction
Syzygium cumini				

Preperation of cotton fabric : The greige cotton fabric was treated with 3 per cent concentration of alpha amylase with 1:50 material to liquor ratio at 60^0C for 45 minutes reaction time, at pH 6-7 (Vigneswaran *et al.,* 2013). The desized cotton fabric was further subjected to enzymatic scouring with 2 per cent enzyme concentration with 1:50 material to liquor ratio for 45 minutes duration at 40^0 C, pH 8. After the treatment, the fabric was rinsed thoroughly, first with hot water and then with cold water to neutralize the enzymatic effect (Ragendran *et al.,* 2011).

Qualitative phytochemical analysis : Freshly prepared extract of the powdered leaves was subjected to phytochemical analysis to find the presence of flavonoids, tannins, phenols according to the procedure described by Gopinath SM *et al.,* 2012; Saidulu Ch *et al.,* 2014).

1. **Detection of tannins**
   Ferric chloride test: To the filtrates, a few drops of ferric chloride solution were added. A blackish precipitate indicates the presence of tannins.
2. **Detection of flavonoids**
   Lead acetate test: Extracts were treated with few drops of lead acetate solution. Formation of yellow color precipitate indicates the presence of flavonoids.
3. **Detection of phenolics compounds**
   Ferric chloride test : Extracts were treated with 3-4 drops of ferric chloride solution. Formation of bluish black color indicates the presence of phenols.

Application of syzygium cumini leaves extract:

Pad dry cure process : To develop Ultraviolet protective fabric, cotton fabrics were treated with *Syzygium cumini* leaves extract in the presence of resin cross linking agent and magnesium chloride by using pad-dry-cure process. The sample was immersed in finishing solution containing 3 per cent (owf) concentration of methanolic leaves extract of *Syzygium cumini,* with 1:20 material to liquor ratio, 50g/l resin cross linking agent (Fixa prêt eco), 10g/l magnesium chloride, at 5pH for 30 minutes. The fabric was then passed through the padded roller on two-bowl pneumatic padding mangle at a pressure of $2kg/cm^2$ with two dips and nips. The fabric was dried and cured in laboratory curing chamber.

Quantitative assessment of ultraviolet protection factor (UPF) : The ultraviolet protective property of cotton fabric treated with *Syzygium cumini* leaves extract in presence of resin cross linking agent and magnesium chloride was evaluated by using UVR TRANSMISSION AATCC-183:2004 test method. The transmission of ultraviolet radiation (UV-R) was determined in the wavelength range of 280-400nm by using Compsec M 350 UV-Visible Spectrophotometer. UVA and UVB percentage transmission were measured. Ultraviolet protection factor was calculated using mean percentage transmission in UVA region (320-400 nm) UVB region (280 -320 nm) according to the following equation:

$$UPF = \frac{\sum_{\lambda 290}^{400} E\lambda \times S\lambda \times \Delta\lambda}{\sum_{\lambda 290}^{400} E\lambda \times S\lambda \times T\lambda \times \Delta\lambda}$$

Where:
Eë = relative erythermal spectral effectiveness
Së= solar spectral irradiance
Të= average spectral transmission of the specimen
³%ë= measured wavelength interval (nm)

Table 3. Grades and Classification of UPF

UPF Range	UVR transmission (%)	Protection category
15 to 24	5.0-2.4	Good protection
25 to 39	3.3-2.5	Very good protection
40 to 50	<2.5	Excellent protection

Assessment of developed UV protective cotton fabric by consumers : The assessment was conducted in Hisar city of Haryana state. Thirty respondents were purposively selected by taking care that the respondents should be female, married and should fall in the age group of 30-45, as females falling in this age group are more receptive towards buying and caring for the clothing needs of the family members such as children, husband, brother in law, mother in law. Questionnaire was prepared for the collection of data regarding the awareness of respondents about the availability of UV protective garments in the market and their opinion regarding the developed UV protective cotton fabric for garment production.

RESULTS AND DISCUSSION

Plants are naturally gifted with number of medicinal compounds also known as phytochemicals. The phytochemicals are non-nutritive chemicals produced by plants for their own protection, but these have been found to protect humans against diseases as studied through recent researches. These includes tannin, alkaloid, flavonoids, and saponin (Edeoga *et al.,* 2005) having biological properties such as antioxidant activity, antimicrobial, stimulation of immune system, modulation of hormone metabolism, anticancer, UV protective and many more (Yadav and Agarwala, 2011). An experiment was conducted to evaluate the methanolic leaves extract of *Syzygium cumini* for the presence of tannin, flavonoids and phenols which have been reported to exhibit UV protective properties (Chaudhary and Mukhopadhay 2012; Sharma *et al.,* 2012). Phytochemical analysis revealed the presence of various secondary metabolites in the methanolic leaves extract of *Syzygium cumini* i.e tannin, flavonoids and phenols as shown in table 4. Thus due to the presence of such phytochemicals methanolic leaves extract of *Syzygium cumini* was applied on cotton fabric to develop and evaluate UV protective property of treated cotton fabric.

Ultraviolet Protection properties of treated cotton fabric : UPF is the scientific term used to indicate the amount of Ultraviolet (UV) protection provided to the skin by fabric. The higher the value, the longer a person can stay in the sun until the area of skin under the fabric becomes red (Dhandapani and Sarkar, 2007). According to experts, including the U.S. Environmental Protection Agency, the technique that best protects the skin against UV radiation is clothing (U.S. Environmental Protection, 2006). Fabrics with UPF values greater than 40 are considered as having excellent UV protection, whereas fabrics with 25-39 translates to have very good UV protection and fabrics with UPF values between 15-24 gives good UV protection as been indicated in table 3.

This study was conducted to develop the UV protective cotton fabric by using *Syzygium cumini* leaves extract and assess the acceptability of developed fabric. Table 5 shows the UPF values, UVA and UVB per cent transmission and UPF rating of the fabric under study. As indicated from the results, the treatment of cotton fabric with *Syzygium cumini* leaves extract improves the UV protection

Table 4. Phytochemical analysis of Syzygium cumini leaves extract

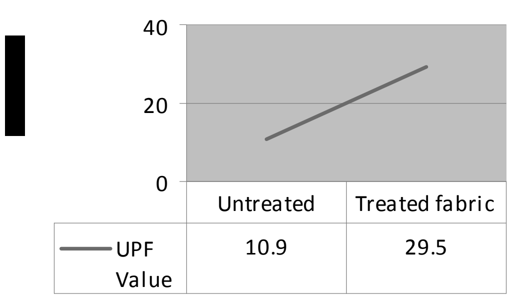
Phytochemical	Plants	Interface		Results
Tannin	*Syzygium cumini*		Blackish precipitates	Positive
Flavonoids	*Syzygium cumini*		Yellow color	Positive
Phenols	*Syzygium cumini*		Bluish black	Positive

property of the cotton fabric. The untreated cotton fabric indicates the UPF value of 10.9 exhibiting poor UV protection and treated cotton fabric exhibit UPF value of 29.5, providing very good UV protection. The UVA and UVB per cent transmission is also discussed as UVA and UVB radiation provides harmful effect on skin; UV-A can penetrate the top layer of skin, thereby damaging the inner layers. UV-B radiation can cause sunburn and is thought to be the major reason for skin cancer as it inhibits the synthesis of DNA, RNA and proteins (Holme, 2003). The data presented in table 5 and graph 2 shows the reduction in UVA and UVB percent

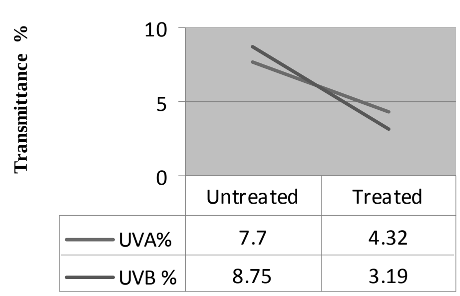
Table 5. Ultraviolet Protection Factor of the untreated and treated cotton fabrics

Fabrics	Ultraviolet Protection Factor (UPF)(AATCC-183:2004)				
	UVA(%)	UVB(%)	UPF Mean (value)	UPF range	Protection category
Untreated	7.70	8.57	10.9	No range	Poor
Treated	4.32	3.19	29.5	25-39	Very good

Graph:1 Ultraviolet protection value of cotton fabric



Graph:2 UVA and UVB percent transmitance of cotton fabric



transmission in cotton fabric, when treated with *Syzygium cumini* leaves extract, thus exhibiting higher UV protection.

The Ultraviolet protection provided by methanolic leaves extract of *Syzygium cumini* extract could be due to the presence of tannin, flavonoids and phenols. These are reported to protect plants from harmful UV rays as well as they are also good UV absorbers as reported by Subramaniyan *et al.,* 2013. Khazaeli and Mehrabani, 2008, analysed sun protective ability of some medicinal plants and observed the high

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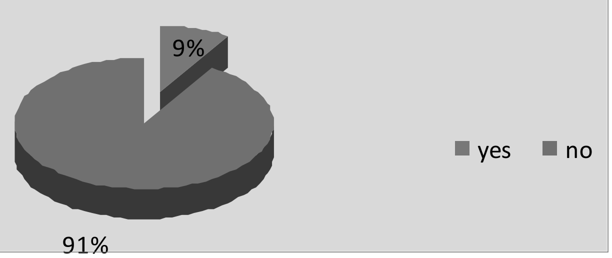
Fig. 1 Awareness regarding the availability of UV protective clothing



SPF value of V. tricolor and rendered such activity due to the presence of phenolics compounds and flavonoids. UV absorbers incorporated into fibers convert electronic excitation energy into thermal energy, function as radical scavengers and singlet oxygen quenchers. The high-energy, short wavelength ultraviolet radiations excite the UV absorbers to a higher energy state; the energy absorbed may then be dissipated as longer wavelength radiations (Das, 2010).

Assessment of developed UV protective cotton fabrics by consumers : This section deals with the awareness of the respondents regarding the availability of UV protective clothes/ garments in market as well as the acceptability of developed UV protective cotton fabric. Different type of garments such as Swin shirts, UV suits, sun suits and sun hats are manufactured by companies and are available in the market, which provide good UV protection (Das, 2010). In Fig. 1, it can be seen that only 9 per cent of the respondents were aware of the availability of UV protective clothes in market while 91 per cent of respondents were not aware. As results revealed, very less number of people are aware of the availability of such UV protective garments, there is a need to disseminate the information regarding the same among masses.

The data from Fig. 2 reveals the opinion of the respondents regarding the acceptability of developed (UV protective) cotton fabric. It was found that the majority of the respondents i.e 87 per cent preferred developed UV protective cotton fabric for female garments, 79 per cent for male garments and 84 per cent for children garments. The acceptability of developed cotton fabric may be attributed to the enhanced performance property of cotton fabric which increases its use in summers especially for outdoor activities. Respondent suggested that commonly used garments such as kurti, shirt, stoles, scarf, jumpsuit hats, caps can be developed by using the developed UV protective cotton textiles and used in day to day life.

The respondents were also shown surface

enriched developed UV protective cotton fabric by using block printing technique and asked for their opinion regarding the its acceptability for garments. The results as shown in Fig. 2 revealed that majority of the respondent i.e 95 per cent gave their acceptability for block printed developed UV protective cotton fabric for female garments followed by 37 per cent for male garments and 17 per cent for children garments. Hence it was cocludecd that as per the consu,er opinion block printed and plain were excepted for making garments.

Fig. 2 Opinion regading the acceptability of developed UV protective cotton fabric

	Female garments	Male garments	Children Garments
UVP cotton fabric	87	79	84
UVP cotton fabric with embelishment	95	37	17

UVP- Ultraviolet protective cotton fabric Multiple responses

CONCLUSION

Now –a-days with more environmental consciousness and more health problems associated with the incidence of skin cancer due to excessive exposure to sunlight as well as the use of synthetic products, consumers are looking for products with additional performance properties, developed through natural sources such as plants. Cotton being the most versatile and one of the favourite fiber for summer, can be treated with *Syzygium cumini* leaves extract which exhibits the potential to enhance its UV protective property thus providing a safe shield from harmful effect of UV radiations not only to outdoor workers but each member of the society when used as apparel.

REFERENCES

Chaudhary, B. and Mukhopadhyay, K. 2012. Syzygium cumini (L.) Skeels: A potential source of nutraceuticals. *Int. Jour. Pharmacy Bio. Sci.* **2** : 46-53

Choudhary, S., Sharan, L. and Sinha, M.P. 2012. Phytochemical and antimicrobial screening of Psidium guajava (L.) leaf extracts against clinically important gastrointestinal pathogens, *J. Nat. Prod. Plant Resour*, **2 :** 524-29.

Cotton Incorporated Lifestyle Monitor.2015. TOP PERFORMANCES. *Lifestyle cotton incorporated monitor*. Retrieved from http://lifestylemonitor.cottoninc.com/tag/activewear/

Crews, P.C., Kachman, S., Beyer, A.G. 1999. Influences on UVR transmission of undyed woven fabrics. *Textile Chemist Colorist.* **31**: 17-21

Das, R.B. 2010. UV Radiation Protective Clothing. *The Open Textile Journal.* **3**:14-21

Dhandapani, R. and Sarkar, A.K. 2007. Antibacterial and UV Property on Silk Substrate. *Jour. Tex. Apparel, Tech. Manag.* **5** : 1-7

Edeoga, H.A., Okwu, D.E. and Mbaebie, B.O. 2005. Phytochemical constituent of some Nigerian Medicinal Plants. *African Journal Biotechnology* **4 :** 685-88

Gopinath, S.M., Rakesh, C.K., Ashwini, P.G.M and Dayanda, K.S. 2012. Preliminary Phytochemcial Evaluation Of Leaf Extracts Of Euphorbia Hirta, Syzygium Cumini Of Siddarabetta, Tumkur District, Karnataka. *International Journal Pharma Bio Sciences* **3** : 431-35.

Holme, I. 2003. 'Versatile technology comes of age', *International Dyer*. **188** : 9-13.

Khazaeli, P. and Mehrabani, M. 2008. Screening of Sun Protective Activity of the Ethyl Acetate Extracts of Some Medicinal Plants. *Iranian Journal Pharmaceutical Research.* **7** : 5-9.

Maske, P.P., Lokapure, S.G., Patil, K. and Disouza, J. 2012. Study on In-vitro Evaluation of Fruits of Syzygium cumini as A Natural Anti-solar Agent. *Research Journal Pharmaceutical, Biological Chemical.* **3** : 349-53.

Ragendran, R. S., Sundaram, K., Radhar, R. and Rajapriya, P. 2011. Bioscouring of cotton Fabrics using pectinase Enzyme its Optimization and Comparison with Conventional Scouring Process. *Pakistan Journal Biological Sciences.* **14**: 519-25

Saidulu, Ch., Venkateshwar, C. and Gangahar, R.S. 2014. Preliminary phytochemical studies of medicinal plant drug: Withania somnifera linn. *Biolife.* **2** : 306-12.

Sharma, S., Mehta, B.K., Mehta, D., Nagar, H. and Mishra, A. 2012. A Review on pharmacological activity of Syzygium cumini extracts using different solvent and their effective doses. *International Research journal pharmacy* **3** : 54-58

Soni, H., Nayak, G., Pate,l S.S., Mishra, K. and Singha,i A.K. 2011. Pharmacognistic Studies of the Leaves of *Syzygium cumini* Linn. *International Journal Research Pharmaceutical Biomedical Sciences.* **2** : 57-59

Subramaniyan. G., Sundaramoorthy, S., and Andiappan, M. 2013. Ultraviolet protection of mulberry fruit extract on cotton fabrics. *Ind. Jour. Fiber Tex. Res.* **38** : 420-23

U.S.Environmental Agency. 2006. EPA sunrise: Sun safety action steps. Retrieved on May,2007, http://www.epa.gov/sunwise/acstionsteps.htm

Vigneswaran, C., Ananthasubramanian, M., Anbumani, N. and Kandhavadivu, P. 2013. Eco-friendly Approach to improve Pectinolytic Reaction and Process Optimization of Bioscouring of Organic Cotton Textiles. *Jour. Eng. Fibers Fab.* **8** : 121-32.

Yadav, R.N.S. and Agarwala, M. 2011. Phytochemical analysis of some medicinal plants. *Journal Phytology.* **3** :10-14

SESSION PROCEEDINGS

AND

RECOMMENDATIONS

National Symposium
on
"Future Technologies : Indian Cotton in the Next Decade"

December 17-19, 2015

at

Acharya Nagarjuna University, Guntur - 522 510

Organised by

Cotton Research and Development Association (CRDA)
CCS Haryana Agricultural University, Hisar-125 004
and
Acharya N. G. Ranga Agricultural University (ANGRAU), Hyderabad
Regional Agricultural Research Station (RARS), LAM, Guntur-522 034

In collaboration with

Indian Council of Agricultural Research (ICAR), New Delhi-110 001
Acharya Nagarjuna University, Guntur - 522 510
Andhra Pradesh Cotton Association, Guntur - 522 510

PROGRAMME

Thursday, December 17, 2015

8.00-9.00 AM : Registration

Inaugral Session

9.00 AM	Invocation	**University Song**
9.05 AM	Lighting of the Lamp	**By the Dignitaries**
9.10 AM	Welcome Address	**Dr E.Narayana, Convener** ADR, RARS, Lam, Guntur
9.15 AM	Presidential Opening Remarks	**Dr K.R.S. Sambasiva Rao** Rector, ANU, Guntur
9.20 AM	Address by Guests of Honour	**Dr S.S.Siwach** Vice-President, CRDA, Hisar **Dr A. Ramasami** Vice-President, CRDA, Hisar **Dr K. Raja Reddy** Director of Research, ANGRAU, Guntur

		Dr N.V. Naidu Director of Extension, ANGRAU, Guntur **Dr T. Ramesh Babu** Dean of Agriculture and Dean of PG Studies, ANGRAU, Guntur **Dr Rajasekhar,** Registrar, ANU, Guntur **Dr N. Gopalakrishnan,** Former ADG(CC), ICAR, New Delhi
10.20 AM	**Release of Publications**	
	a) Book of Papers	**Dr. A. Padma Raju,** Vice-chancellor, ANGRAU
	b) Book of Oral Presentations	**Dr K.R.S. Sambasiva Rao,** Rector, ANU
	c) Book of Abstracts	**Dr K. Raja Reddy,** Dircctor of Research, ANGRAU
	d) HDPS in Cotton	**Dr N.V. Naidu,** Director of Extension, ANGRAU
	Presentation of Awards	
	a) Life Time Achievement Award	
	b) Corporate Advisors	
	c) Private Public Partnership Award	
	d) Honour to Sponsors	
10.45 AM	Address by the Chief Guest	**Dr A. Padma Raju** Hon'ble Vice-Chancellor, ANGRAU, Guntur
11.00 AM	Presidential Closing Remarks	**Dr K.R.S. Sambasiva Rao** Rector, ANU, Guntur
11.10 AM	Felicitation	
11.20 AM	Vote of Thanks	**Dr M.S. Chauhan** Secretary, CRDA, CCS HAU, Hisar
11.25 AM	National Anthem	
11.30 AM	Hi-Tea	
12.00 AM	Technical Session	

Inaugural Session

President : Dr. K.R.S. Sambasiva Rao, Rector, ANU, Guntur

Chief Guest : Dr. A. Padma Raju, Honourable Vice Chancellor, ANGRAU

Rapporteurs : Dr. B. Sree Lakshmi, Principal Scientist (Pathology), RARS, Lam

The National Symposium on "Future Technologies: Indian Cotton in the Next Decade" jointly organized by Cotton Research and Development Association and Acharya N. G. Ranga Agricultural University is being held at Acharya Nagarjuna University, Guntur during 17th to 19th December, 2015. Dr. V. Chenga Reddy, the Organizing Secretary, welcomed the dignitaries on to the dias. Dr. A. Padma Raju, Honourable Vice Chancellor, ANGRAU was the chief guest of the function. Dr E. Narayana, Associate Director of Research, Regional Agricultural Research Station, Lam, Guntur, Dr. K. Raja Reddy, Director of Research, Dr N. V. Naidu, Director of Extension, Dr T. Ramesh Babu, Dean of Agriculture, Dr Neeraja, Dean of Home Science, Dr. K. Rosaiah, Nuzveedu Seeds and former ADR, RARS, Lam, Guntur, ANGRAU, Dr S. S. Siwach, Vice President, Dr Rama Swami, Director of Rasi Seeds and Vice President, Dr M. S. Chauhan, Secretary, CRDA Dr Rajasekhar, Registrar, ANU, Dr. K. R. S. Sambasiva Rao, Rector, Dr. G. Rosaiah, Professor and Head, Department of Microbiology, ANU, Dr N. Gopalakrishnan, Principal Scientist (Biochemistry), CICR, Coimbatore and Former ADG (Commercial Crops), ICAR, graced the occasion. Dr. K. R. S. Sambasiva Rao, Rector, ANU presided the inaugural session and conducted the proceeding. The inaugural session started with invocation song followed by lighting of lamp by the dignitaries.

The President of the function welcomed all the guests and participants. The convener of the Symposium, Dr E. Narayana, Associate Director of Research, Regional Agricultural Research Station, Lam, Guntur delivered the welcome address. Indian farmers faced the problem of *Helicoverpa* with *Bt* technology, however the latest outbreak of pink boll worm in Central and South India and whitefly in North India challenged all of us and the present Symposium provides the correct platform to address these challenges, plan the strategies to increase cotton yields. He also stressed the importance of mechanization from seed to seed in cotton production also the use of short duration cotton varieties in cotton based cropping system.

Dr. K. R. S. Sambasiva Rao, Rector, ANU emphasized the progress made in cotton production and per capita yield since 2003 in India. Research on crop improvement, in particular, fibre quality should be strengthened to capitalize the global market. The debatable issues include reduction in pesticide usage, pest and disease problems, reduction in seed cost, need for preservation of germplasm etc.

Dr S. S. Siwach, Vice President, CRDA, informed the house about the establishment and achievement of CRDA at CCSHAU, Hisar. He raised the problem of white fly during *kharif* 2015-16 in North India and stressed the importance of interdisciplinary approach to tackle challenging problems in cotton production.

Dr A. Ramaswami, Director of Rasi Seeds and Vice President, CRDA stressed the importance of seed production and distribution system and public involvement helped to achieve the biggest targets in a commercial crop like cotton. Scientists should concentrate on conventional breeding to match the emerging problems. Farmers are concentrating on use of hybrids putting tremendous pressure on seed supply system hence there is a need to produce seed at constant cost at farmers' disposal.

Dr. K. Raja Reddy, Director of Research, ANGRAU, remarked the dependence of >60 per cent people depend on agriculture and six million people are associated with cotton production and industry. With the advent of *Bt* technology and incorporation of *Bt* gene in cotton the entire seed production is with MNCs. He also mentioned the importance of research on surgical cotton, mechanization, ideotype breeding for mechanical picking, early maturing types with synchronous maturity as researchable issues. The Government should be aware of the recommendations of the symposium.

Dr N. V. Naidu, Director of Extension, ANGRAU remarked that farmers are cultivating cotton in light soils as they get the minimal guaranteed income. Integrated Pest Management and other technologies were developed at RARS, Lam to meet the challenges from time to time. He stressed the need to address the problems arising due to changing climate scenario.

Dr T. Ramesh Babu, Dean of Agriculture, ANGRAU explained the achievements of Lam Farm in cotton. He emphasized that refugee concept is not being followed by farmers in Bt cotton.

The Chief Guest Dr. A.Padma Raju, Hon'ble Vice-chancellor, ANGRAU released the "Book papers", Dr.K.R.S.Samba Siva Rao, Rector, ANU released the "Book of Oral Presentations" while Dr.K.Raja Reddy, Director of Research, ANGRAU released the "Book of Abstracts". A "Technical Bulletin on High Density Planting System in Cotton" was released by Dr. N.V.Naidu, Director of Extension, ANGRAU.

The CRDA honoured the following Scientists for their Life Time Achievement Award

1. Dr Raju D. Shroff, CMD, UPL Pvt. Ltd., Mumbai
2. Dr. K. Ravindranadh, Former Cotton Breeder, RARS, Nandyal
3. Dr. Joginder Singh, Former HOD, Entomology, Punjab Agricultural University, Ludhiana
4. Dr. M.S. Chauhan, Senior Pathologist CCS HAU, Hisar, and Secretary, CRDA, Hisar
5. Dr. S.K. Banerjee, Former, Sr. Entomologist, CICR, Nagpur
6. Dr. B.L. Chopra, Sr. Pathologist, Punjab Agricultural University, Ludhiana
7. Dr. C.D. Mayee, Former Vice Chancellor, PDKV, Akola, Director , CICR, Nagpur and Chairman, ASRB, New Delhi

The Association also honoured the following Corporate Advisors.

Corporate Advisors

1. Dr. M.Prabhakara Rao, MD, Nuziveedu Seeds, Hyderabad
2. Dr. R.K. Malhothra, Indofil Pvt. Ltd., Mumbai

The Association also honoured the following Private Public Partnership Awardees in different categories.

Private Public Partnership Awards

1. United Phosphorous Limited - Pesticide Industry Category
2. Rasi Seeds Private Limited - Seed Industry Category
3. Bayer Crop Sciences - Mechanical Harvesting Category
4. Monsanto Private Limited - Biotechnology Category

5. Veera Reddy Seeds -Budding Industry Category

The organizers honoured the sponsors of the Symposium

1. Indofil India Limited, Mumbai
2. Rasi Seeds Private Limited, Attur
3. United Phosphorous Limited, Mumbai
4. DOW Agro Seeds, Mumbai
5. Bayer Crop Sciences, Hyderabad
6. Pesticides India Limited, Gurgaon

The Chief Guest Dr. A.Padma Raju, Hon'ble Vice Chancellor, ANGRAU addressed the august gathering. He expressed that the farmers feel cotton as the safest crop though a challenging crop. Development of straight varieties with *Bt* technology is under progress. Regional Agricultural Research Station, Lam Farm is the leader in developing Integrated Pest Management Technologies in Cotton. The resurgence of pink bollworm during *kharif* 2015-2016 indicate the ever ending fight with insect pests. He remarked the need to strengthen the traditional breeding. Development of short duration varieties/hybrids, high density planting system are the need of the hour to tackle the pest problems and increased picking cost. He advised to terminate cotton crop after two picking by February and incorporate pulse crop in cotton cropping system to manage the pink bollworm menace.

The CRDA also honoured the officers on the dias Dr. S. S. Siwach, Dr. A. Ramasami, Dr. K. Raja Reddy, Dr. N. V. Naidu, Dr. T. Ramesh Baby, Dr. Rajashekher, Dr. N. Gopalakrishan, Dr. M. S. Chauhan, Dr. E. Narayana, Dr. V. Chenga Reddy, Dr. K.R.S. Smaba Siva Rao and Dr. A. Padma Raju Rosaiah by giving them the Momento and Shawl.

The session concluded with vote of thanks by Dr.M.S.Chauhan, Secretary, CRDA, Hisar.

Session I : Lead Papers

Chairman : Dr N.V. Naidu, Director of Extension, ANGRAU
Co-chairman : Dr. T.Neeraja, Dean Home Science, ANGRAU
Rapporteurs : Dr.S.Bharathi, Dr. S.Rajamani, G. Bindu Madhavi

1. Cotton productive strategy for the next decade by seed industry prospective - Dr Vipin S Debonakar : He stressed on the global challenges in cotton, way outs, potential transgenic solutions, agronomic solutions. Further he ascertained that these can be applied to Desi cottons. He stressed the importance of improving seed production efficiency by promoting use of male sterile system, focus on plant architecture in breeding to meet the future needs of high density planting system, development of strong post harvest processing facilities for mechanical picking and breeding approaches for specialty fibres. Under long term strategy, selection of resistant germplasm along with agronomic and integrated pest management should be adopted to tackle the whitefly menace. He ascertained that the concerted effort on all these issues will benefit farming community and seed industry, thereby national economy.

2. Wide strike ™ cotton, insect protection technology by Dow Agrosciences : Wide strike is the trade name of Dow Agrosciences insect resistant transgenic cotton.It was reported from their

BRL trails, it provides tolerance to wide spectrum of insects *viz.*, bollworms and cutworms. It expresses the tolerance throughout the crop growth. Compared to the available Bollgard technology, It has a different promoter for cry1 AC hence it delays resistance development. It is not effective against sucking pests and the refugia recommendations are similar to bollgard and it is aimed to be released during 2017 cropping season.

3. Prospects of *Bt* cotton in Haryana - Dr. S. S. Siwach : Dr. S. S. Siwach, Director of Research, CCSHAU, Hisar presented the lead paper on "Prospects of *Bt* cotton namely, sudden rise in the hybrid cotton acreage, phenomenal incease in the production and productivity of county. Change in the farmers preference for agronomic traits after introduction of *Bt*, significant reduction in pesticide usage for bollworm after introduction of the technology, more preference to big boll hybrids in the country etc. He also emphasized the problems namely; sudden wiltring of plants, increased damage of whitefly, threat of minor pests like mealybug, hybrid bug, aphids and thrips, resistance to *Bt* gene, improvement of fibre quality to meet the industrial needs etc. He also emphasized the upcoming challenges like changing wheather pattern, resistance management, hybrid seed production and apprearance of new pests.

Technical Session (combined) :

Chair man : Dr N.Gopalakrishnan, Former ADG (CC) ICAR, New Delhi
Co- chairman : Dr. D.Monga, Head, CICR Regional Station, Sirsa
Rapporteurs : Dr.S.Bharathi, Dr. S.Rajamani, G. Bindu Madhavi

Invited Papers

1. Wide hybridization in cotton problems and prospects - Dr. Pankaj Rathore : Wild species have been utilized for transfer of resistance to various insect pests diseases including cotton leaf curl disease for improving the cultivated cotton species especially G.hirsutums. The main aim is introgressing the genes from the wild to the cultivated spp to increase the diversity in the modern cultivars. He stressed that the research on better understanding of the complex genus Gossypium germplasm and also its utilization in future breeding programmes. He also elucidated that the genus comprises species with differing ploidy levels and represents a high degree of variability from highly improved allo tetraploid species to wild diploid species whose beneficial characteristics should be exploited.

2. Genetic enhancement in cotton through conventional and genetic engineering approaches – Dr. O.P.Tuteja : He stressed that to meet the ever increasing market demand plant breeders need to develop cultivars by using elite and diverse germplasm lines. The emphasis on wide crossing is very much needed for transfer of desirable traits from wild species or land races. The resistant varieties LK 861, LPS 141 (Kanchana) can be conveniently used for development white fly resistant lines. He emphasized the development of early maturiing genotypes with synchronous opening suitable for high density population system and mechine picking, utilization of Gene transformation and marker assisted selection as tools to overcome the limitations of conventional breeding in incorporating useful traits in cotton germplasm, developing multiple adversity resistance lines through genome mapping, finger printing, gene tagging and transformation and to develop germplasm lines for multiple insect resistance. He also mentioned the importance of the development of germplasm suitable for organic farming which is the need of the hour.

3. Weed management present status and future strategies for cotton – P.Nalayani : She expressed that integrated strategies need to adopted for sustainable weed management and to avoid the problem of development of super weeds which is encountered in developed countries (USA, Brazil). She mentioned the critical period of crop weed competition and different chemical; and non chemical methods viz; Solarization, mulching, Stale seed bed technique, mechanical removal, growing compatible intercrops and use of pre and post emergence herbicides. She also suggested the use of microencapsulation technology for controlled release of active ingredient for the extended period of weed control. She also discussed elaborately the pros and cons of herbicide tolerance genetically modified crops with special reference to cotton.

4. Disease scenario of cotton and management strategies in India – Recent Development – Dr. D. Monga : He explained the present day disease scenario and various integrated disease management modules to be adopted to overcome crop losses. The diploids and desi cottons need to be encouraged. He stressed the need of redefining the strategies for the integrated management of diseases causing losses in terms of yield and quality. He explained the role of bioagents and SAR chemicals in disease management. He discussed the new management strategies for cotton leaf curl disease to overcome the breakdown of resistance for this important crop. Finally, he focused on the emerging disease problems and development of diseases visa-vis climate change to understand disease epidemiology and for fine tuning of management strategies.

5. Resource conservation and mechanisation in cotton - Dr. E.Narayana : He highlighted the techniques such as growing of cotton seedling in trays for gap filling, drip irrigation, mulching for water conservation, zero tillage sowing and high density planting in cotton for resource conservation. He also enlightened the importance of the mechanization and available machinery such as planters and mechanical pickers in cotton through public private partnership.He also stressed the importance of defoliation and also mentioned the role of growth regulators in manipulation of the cotton plant suited for mechanical harvesting.

The following oral presentations were done on 17-12-15 during different concurrent sessions of Crop Improvement, Biotechnology and Post harvest Technology, Crop Improvement, Biotechnology and Post harvest Technology and Crop Protection and Biosafety.

Concurrent Session II : (Crop Improvement, Biotechnology and Post harvest Technology)

Oral Presentations

Chair man : Dr. R. S. Sangwan Head Cotton, CCSHAU, Hisar
Co- chairman : Dr. Pankaj Rathore, Director, PAU Regl. Station, Faridkot
Rapporteurs : Dr. S. Rajamani, Dr. K. V. Shiva Reddy

1. Cotton in Gujarat – A Review - Dr. B. G. Solanki : He emphasized on the Cotton improvement work which started in earnest at Bharuch (Middle Gujarat) with the establishment of a Research Centre there in 1926. The variety BD 8 was given out in 1936. As a result of intensive work on hybridization a variety named Vijay was evolved in 1943. This variety, possessing wilt resistance, higher ginning percentage and better fibre quality found favour in the whole of Middle

Gujarat and parts of South and North Gujarat. This was followed by the most popular variety, Digvijay released in 1956. Then came G.Cot.11, a high yielding, early maturing variety has been released in 1979. subsequently a high yielding early maturing variety G.Cot.17 evolved was released in 1995 for middle Gujarat. This was totally replaced by G.Cot.23 released in 2000. Most recently a variety G.Cot.25 has been released in 2010 for whole Gujarat. Due to introduction of Bt cotton and favourable season and crop condition since last ten years, Gujarat occupied the highest position in cotton production and productivity at National level. Due to *Bt era*, in some area the socio-economic level of cotton growers was boosted up. Mealybug havoc after 3-4 years of *Bt* introduction in Gujarat was noticed and was tackled very well. Thereafter, pink boll worm(PBW) issue became headache for cotton researchers as well as growers. Besides this, illegal *Bt*, avoidance of refugee crop, abnormalities in cotton morphology are the major issues in cotton cultivation and in coming years there may possibilities of new unknown issues in cotton cultivation.

2. Evaluation of *Bt* cotton hybrids for yield and fibre quality - Dr. K. V. Shiva Reddy : He pointed out that highest boll/plant was recorded by ACH 1 BGII followed by First class BG II. Higher boll weight was observed in Ankur 2595 BGII and ACHH 2 BGII hybrids. Whereas, Ankur 5464 BG II recorded highest 2.5 per cent span length and Ankur 2595 BGII and JKCH 8905 BG II shown maximum bundle strength. The desirable hybrids in respect of seed cotton yield are KSCH 232, Ankur 2595 and SP 7517 whereas, with respect to fibre properties Ankur 2595 and KCH 3021 were identified.

3. Genetic Improvement for fibre quality traits in *arboreum* cotton - Dr. V. N. Chinchane : He said that fifteen newly developed strains of *arboreum* cotton were evaluated for yield and fibre quality traits along with checks under rainfed condition. The strain PA 739 recorded highest seed cotton yield (1465 kg / ha) followed by PA 778 (1400 kg / ha) and PA 796 (1386 kg /ha). A range of 34.03 (PA 791) to 36.83 per cent (PA781) was observed for ginning outturn amongst the strains under testing.The strain PA 781 recored highest ginning outturn (36.83 %) followed by PA 778 (36.31 %). In quality paramenters, most of the newly developed strains are superior than the check varieties. In respect of fibre length measured as 2.5 per cent span length, all the strains except PA 739 were superior to the check varieties. Majority of the new genotypes showed distinct superiority for short fibre content over check varieties. Considering averall fibre quality parameters,genotypes PA 789 and PA 794 were found superior fibre quality traits.

4. Resurgence of *desi* cotton – A status of past, present and future - Dr. A. Manivannan : He said that Since the introduction of *Bt* cotton area under *desi* cotton has been reduced to less than 1 per cent. *Desi* cotton known for its ability to grow in marginal environment especially *herbaceum* prefers to grow in coastal region. *Desi* cotton possesses resistance to range of insect pests namely hoppers, whiteflies, thrips and aphids. *Desi* cotton almost exhibits immune to the vector borne leaf curl virus. Due to short, coarse and weak fiber traits make them unsuitable for modern machine textile industries. In spite of poor fibre traits, these short stable cotton used for denim, upholstery and surgical cloths. Recent past the trend is reversing, the demand for short stable cotton is 2 per cent however the production is 1 per cent; this makes a lot of hope for increasing the area of *desi* cotton. Concentrated varietal improvement resulted in the release of long linted variety like PA-255 (Parbhani), DLSA 17 (Dharwad), MDL2463 (A.P) and Jawahar Tapti of arboreum cotton with fine fibre qualities created a hope to satisfy the requirements of textile industry. Recent havoc of whitefly and leaf curl incidence in *hirsutum* demands a hardy genotype; by the virtue of above facts the true resurgence of *desi* cotton is not far away.

5. Genetics of seed cotton yield and its contributing characters in cotton (*Gossypium hirsutm* L) - Dr. S. Rajamani : He pointed out that all the traits governed by additive x dominance component of epistatic gene action except lint index which is governed by dominance x dominance gene action. Breeding methods like heterosis breeding would be followed for development of commercial hybrids to obtain higher yields as most of the traits were governed by epistatic gene action. In addition to heterosis breeding special mating designs like bi-parental mating and inter mating in early generations would be adopted to isolate superior segregants from future generations. The order of parents in which crosses must be effected should clearly revealed by the study to obtain superior transgressive segregants. The fixable component of epistatic gene action was playing major role in governing the character. Hence pedigree method of breeding may be followed for improvement of the character.

Concurrent Session III : (Crop Production, Mechanization and Economic Development)

Oral Presentations

Chair man : Dr. B. G. Solanki, Head, NAU Main Cotton Research Station, Surat
Co- chairman : Dr. P. Nalayini, Principal Scientist, CICR Regl. Station, Coimbatore
Rapporteurs : Dr. S. Ratna Kumari and S. Bharathi

1. **Agronomic evaluation of popular *Bt* cotton hybrids in Marathwada region under rainfed conditions - Dr. A. D. Pandagale :** He said that hybrid Ajeet 155 *Bt* recorded highest seed cotton yield and boll weight and was *at par* with Dr. Brent. Reduction in number of bolls and boll weight was noticed in closer plant spacing however was compensated for seed cotton yield by 6.82 per cent because of higher plant population. This resulted to increased monetary values in closer spacing in terms of GMR and NMR significantly. The interaction of hybrid x spacing revealed that Mallika hybrid performed better whereas hybrids Ajeet 155 *Bt* and Dr Brent *Bt* were similer under both spacings.

2. **Productivity and profitability of BGII cotton hybrids as influenced by different planting geometry and nitrogen levels under rainfed conditions in vertisols of Andhra Pradesh - Dr. S. Jaffar Basha :** He said that higher monopodia/plant, kapas yield, oil percentage, net returns and benefit cost ratio were observed under closer spacing. The number of bolls/plant, *kapas* yield, net returns was observed with Bunny BG II hybrid and was *on par* with Mallika BG II. Higher boll weight was observed in Mallika BG II. *Kapas* yield, net returns and BCR was significantly higher with the application of 180 N kg/ha. Biotech cotton confers improved pest (bollworm) management and retention of early formed fruiting parts leading to higher and earlier boll load. The plants are also early in maturity. In India, *Bt* hybrids had short stature along with inbuilt resistance to bollworm leads to retention of early formed fruiting parts and promotes earliness by 20-30 days. The plant had shallower roots and produced less dry matter and also retain more bolls particularly the early formed ones at lower nodes. Higher sink in *Bt* cotton leads to lower source to sink ratio, faster senescence and crop maturity compared to the non *Bt* version. Early fruit load, coupled with faster fruit load could constrain nutrient supply leading to smaller plants and may lower the yield potential. To overcome these potential problems changes in agronomic practices are needed for achieving maximum benefits from the technology.

3. **Physiological assessment for drought tolerance in cotton *hirsutum* genotypes under rainfed conditions in vertisols - S. Ratna Kumari :** She pointed out that under rainfed conditions, the entries *viz;* BGII 802, CNH 14, L 765, L788, BHC 2413, CA 105, L761, L770, RHC 0717 and LRA 5166 recorded higher RWC, the entries *viz;* H 1454/12, SCS 793, BGII S 802, HAG 805, CSH 1111, L 765, IH 70, RHC 0717,H1465/12 and ARBH 2004 recorded higher specific leaf weight and the entries *viz;* L 761, GBHv 177, L 770, L 762, ARBH 2004, H1454/12 and IH 70 recorded higher SCMR values. The per cent reduction in seed

cotton yield under rainfed conditions ranged from 11.49 to 49.36. The entries *viz;* IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBhv 177 recoded higher seed cotton yield under rainfed conditions and the higher seed cotton yield in these entries was associated with the drought tolerance parameters to drought with more than two contributing characters of drought.

4. Empowerment of women to mitigate drudgery in cotton picking - Dr. Kusum Rana : She emphazied that Women in Haryana are involved in most of the agricultural operations *viz.,* sowing, weeding, harvesting, post-harvest activities picking. Hisar is a pre-dominantly cotton growing district. During experiment time and activity profile, work output and acceptability of the cot bag was assessed. They reported very severe pain in palm, wrist, fingers, neck and shoulders. To mitigate these problems cotton picking bag developed by CCSHAU, Hisar was recommended. The results revealed that by using conventional bag the rural women could pick upto 40 kg of cotton in 7hr and earned Rs 200/day but by using cotton picking bag they could pick 50 kg of cotton in 7 hr, thus, earning Rs 250/person/day. Adequate rest pauses coupled with training on use of proper body postures along with light exercises for back and shoulders need to be given during the work to delay the onset of fatigue and its recuperation.

5. Effect of macronutrients and liquid fertilizers on the growth and yield of *Bt* cotton (*Gossypium hirsutum* L) under irrigation - Dr. Vinayak Hosamani : He pointed out that application of three levels of macro nutrients (75, 100 and 125% RDF) was tried and foliar spray of liquid fertilizers of nutroplus of 1 per cent $MgSO_{-4}$ (Mangala $MgSO_4$) + 0.5 per cent $ZnSO_4$ (Mahazinc) and 2 per cent KNO_3. The results revealed that application of 125 per cent RDF recorded the highest seed cotton yield, total number of bolls harvested/plant, seed cotton yield/plant, leaf area, leaf area index, dry matter production and its distribution, gross returns, net returns and B:C ratio. Among the liquid fertilizers, foliar spray of liquid fertilizer, Bio 20 @ 3 ml/1 recorded significantly higher seed cotton yield, bolls harvested/plant, seed cotton yield/plant, leaf area, leaf area index, dry matter production and its distribution, gross returns and net returns.

Concurrent Session IV : (Crop Protection and Biosafety)

Oral Presentations

Chair man : Dr. S. K. Banerjee, Former Principal Scientist, CICR, Nagpur
Co- chairman : Dr. B. L. Chopra, Former Sr. Cotton Pathologist, PAU, Ludhiana
Rapporteurs : Dr. S. L. Bhattiprolu, Dr. Sesha Mahalakshmi

1. Population dynamics of target and non-target pests in transgenic cotton - U. B. Hole : He said that there were no difference between the transgenic and non-transgenic hybrid in their relative susceptibility to cotton jassids, *Amrasca biguttula biguttula*, thrips, *Thrips tabcaci*, aphids *Aphis gossypi*, white fly, *Bemesia tabaci* and mealy bug, *Phenacoccus solenopsis* . Thus, the transgenic hybrid does not afford any protection to sucking pests of cotton and their tolerance or resistance is mainly dependent on the morphological or genetic base. Bollworm incidence was completely absent in transgenic cotton hybrid as no square and boll damage was observed. Whereas non-transgenic hybrid recorded higher damage and significantly differed from transgenic hybrid. Besides this, significant difference in seed cotton yield was also observed during both the cropping season. Seed cotton yield of transgenic hybrid was significantly greater than that of the non-transgenic hybrid under protected condition. The major bollworms *Helicoverpa armigera*, *Earias vittella* and *Pectinophora gossypiella* were effectively controlled in transgenic hybrid. Thus, transgenic hybrid can play a major role in combating pest problem thereby reducing insecticide usage in cotton ecosystem and helps to maintain ecobalance by conserving natural enemies.

2. Integrated management of foliar diseases in cotton - Dr. S. L. Bhattiprolu : She tried three modules to develop integrated management of foliar diseases in cotton. Pooled data showed that the modules were significantly superior against Alternaria leaf spot and bacterial blight in Jadoo BG II and RCH BG II. Modules I and II significantly reduced grey mildew in both the hybrids. Module II and III gave best control of rust in Jadoo BG II while module I and III were superior in RCH 2 BG II. All three modules resulted in significant increase in the yield of Jadoo BG II while modules I and II gave superior yields in RCH 2 BG II. Module III resulted in highest Incremental Benefit Cost Ratio (IBCR) of 1.35 in Jadoo BG II followed by module I while module II gave maximum IBCR of 1.30 in RCH 2 BG II.

3. Evaluation of spacing and spray schedule for management in bollworms in HDPS cotton - P. W. Nemade : He said that minimum larval population of bollworm was observed. Interaction effect of spacing and modules were found non significant. Module 3 effectively managed larval population of bollworms whereas minimum green fruting bodies damage was observed at both the locations. Maximum damage of green fruting bodies was noticed at both the location. Per cent open ball damage data was found significant but their interaction effect were non significant. Minimum open ball damage was observed whereas maximum open ball damage was recorded. Data recorded on per cent loculi damage was found significant however their interaction effect found non significant. Minimum loculi damage was observed. Maximum seed cotton yield was recorded in S2M2 whereas minimum was recorded in S1M4. Thus, application of (flubendamide 480 SC @ 50ml/ac followed by indoxacarb 14.5 SC @ 100 ml/ac followed by fenvalerate 20 EC @ 160 ml/ac) was found superior in management of bollworms resulted in getting higher seed cotton yield and net monetary returns in high density system of cotton.

Friday, December 18, 2015

Session - V : Lead Papers

Chairman : Dr.S.S. Siwach, Director of Research, CCS HAU, Hisar

Co chairman : Dr.Vipin S. Dagoanokar, Bayer Crop Science

Rapporteurs : Dr.S.Rajamani, Dr. M. Sesha MahaLakshmi, Sri G. Bindu Madhavi

1. Cotton crop protection key trends and solutions - Dr Asif Tanweer : He emphasized about the changing pest scenario on *Bt* cotton, issues regarding development of resistance, reasons for development of resistance, strategies for reducing the resistance development and new insecticide molecules under development from Bayer crop science. The chemicals which had phytotonic effect should be used at early stages of crop growth. Alternate insecticides to synthetic pyrethriods for control of pink bollworm in cotton should be identified to avoid adverse effects on sucking pests.

2. Impact of elevated CO_2 on cotton productivity - A climate resilience - Dr. N. Gopalakrishnan : He emphasized the effect of elevated CO_2 on plant growth parameters, yield and herbivore incidence. He also stressed upon the contribution of cotton production on green house gas emissions both directly at field level and indirectly at processing level at textiles. He stressed upon the measures to be taken for mitigating the green house gas emissions from agricultural sector. Effect of elevated CO_2 on weed emergence should also be studied as a future thrust. He remarked on the interactive effects of multiple environment factors on plant responses to rising CO2 requires a careful study. Optimization of sustainable and natural fertilizing sources including nitrogen fixing crop rotations, composts and composted manures in cotton production helps for adaptation to climate change. He suggested that the concerted efforts in forecasting the likely effected parameters of climate change, its probable impacts and its mitigation strategies for sustainable production of commercial crop like cotton.

3. Functional finishing of cotton textiles – Dr. A. Sarada Devi : She enlightened about the new techniques like Nanotechnology, Plasma enhance chemical vapour deposition (PECVD) and Layer by Layer (LbL) assembly, Use of Phase change materials etc which had resulted in revolutionary changes in the area of textile finishing. She also explained the possibility of altering cotton fabric and make that thermal regulatory, antimicrobial, UV protective and so on. She emphasized on the importance of the natural fibre blended with nano zinc pyrothane derivatives act as antimicrobial properties and the finished fabric will be an ideal health care textile that control the infections in hospitals. Even though the dual nano finished fabrics was estimated to be 20-25 per cent higher than unfinished fabrics, it is durable upto 15 washes and in bulk production, the cost can be reduced to 10-12 per cent.

Session - VI : Young Scientist Award Presentation

Chairman	:	Dr.N. Gopalakrishnan, Former ADG (CC) ICAR, New Delhi
Evaluation Committe	:	Dr. D. Monga, Dr. B. G. Solanki, Dr. S. K. Banerjee, Dr. Joginder Singh

A total of 9 members presented for young scientist award on different aspects

1. Molecular characterization of upland cotton by using PADP markers - Dr. J. D. Deshmukh : He evaluated 15 genotypes of G. *hirsutum* L. to study the genetic diversity by using Random Amplified Polymorphic DNA (RAPD) analysis. Polymerase chain reaction (PCR) was carried out by using 25 random decamer primers. Twenty one primers were found polymorphic and produced 149 bands with 7.0 bands per primer. The polymorphism percentage ranged from 20 to 100 per cent. The genetic similarity coefficient for all genotypes ranged from 0.65 to 0.86 per cent. Cluster analysis separated in to three clusters which were corresponded well with their centers or sub centers or genetic relationship.

2. Utilization heterotic group of cotton and forming sub groups for further exploitation based on combining ability pattern - Dr. H. G. Kencharaddi : He emphazied on the principle of population improvement for combining ability has been extended in this study to a self pollinated crops. Deviation are identified and it is likely that lines belonging to this elite group may differ with respect to identity of dominant favorable allele present in them. Hence the next course of action should be recombine elite combiners to develop a new population to initiate the next cycle of reciprocal recurrent selection against a single testers or combination of testers. The elite high combiner lines identified from opposite populations are expected to be genetically diverse. Hence the crosses obtained from these elite combiners are expected to be potential. The trangressive segregants distributed in population I and II were classified in to positive and negative transgressive segregants based on the sub grouping of F_4 lines with respect to reciprocal tester, common and diverse testers respectively where positive transgressive segregants are showing positive gca effect with the opposite parents hence they combined well the both parents. Similarly negative transgressive segregants are those which are showing significant negative *gca* effect with the opposite parent.

3. Genetical and biochemical basis of cotton leaf curl disease in upland cotton - Dr. Anuradha Godara : She pointed out that the inheritance of cotton leaf curl virus disease indicated the duplicate dominant epistasis(15:1). No complementary gene interaction was observed in cross with susceptible parents for CLCuD resistance. Scaling tests revealed that additive-dominance model was fit for the characters, namely, Days to first flower. These different biochemical parameters viz. tannin, phenol, gossypol provides defense mechanism to plants so have higher content in resistant and tolerant plants while susceptible have lower values. Also, sugar act as substrate for insects that's why susceptible plants have higher sugar content as compared to tolerant ones. However, there is no threshold level studied so far as it depends upon environmental conditions, genotypes, maturity stages and also varies from plant to plant.

4. Study of molecular variability of *Alternaria* spp on *Bt* cotton - Dr. G. N. Hosagoudar : He said that the PCR amplification and sequencing of ITS rDNA region of fungus was best molecular tool for identification of *Alternaria* spp. This is the first time of a sequence of *Alternaria dianthi* and two *Alternaria* spp. isolated from *Bt* cotton are to be publishing in this national symposium. The analysis of genetic variation in plant pathogen populations is an important prerequisite for understanding the evolution in the plant-patho system. Polymerase chain reaction (PCR) based molecular markers are useful tools for detecting genetic variation within populations of plant pathogens. Random Amplified Polymorphic DNA (RAPD) was used to detect the variation among the 17 isolates of *Alternaria* spp collected from different districts of north Karnataka. Polymerase chain reaction (PCR) based molecular markers are useful tools for detecting genetic variation within populations of plant pathogens. Random amplified polymorphic DNA (RAPD) markers have been widely used for estimating genetic diversity in natural populations. The analysis of RAPD polymorphism in isolates of *Alternaria* spp from different agro climatic regions across North Karnataka revealed the occurrence of high level of polymorphism indicating wide and diverse genetic base.

5. Jasmonic acid and salicylic induced protection against cotton leaf curl disease - Rituraj : She highlighted the effectiveness of Jasmonic acid (JA) and salicylic acid (SA) spray against CLCuD. Response of different American cotton accessions namely RS 921, LH 2076, PIL 8, Ankur 3028 BGII and a *desi* cotton variety LD 694 to JA and SA in the induction of proteins for protection against cotton leaf curl disease (CLCuD) was studied. JA was found to be more effective than SA in the induction of proteins. The respective controls exhibited higher values for disease incidence and disease severity. The present study suggests that application of JA and SA results in the induction of proteins of different molecular weights which probably resulted in imparting tolerance against CLCuD whereas, PCR analysis showed that induced proteins were not able to eliminate the presence of virus particles. So, we can say that these chemicals can be used as an alternate to viricides in near future.

6. Detection of pink bollworm, *Pectinophora gossypiella*, Saunders infestation using Soft X ray machine - Dr. S. Nandini : She standardizated X ray radiography methodology for the detection of pink bollworm infestation in cotton bolls. Studies revealed that the controllable input electrical parameters of the X ray machine *viz.*, voltage, current and exposure period required for the detection of internal infestation varied widely for cotton bolls compared to stored grains and fruits tested by other scientists. High voltage and current were required for dense cotton bolls to ensure adequate penetration of radiation.

7. Emerging insect pests of *Bt* coton in middle Gujarat - Dr. M. B. Zala : He said that there is a need to keep vigilance on the emerging pests under the changing cropping system and issue the periodical advisories for timely IPM intervention.

Due to changes in the agroecosystem, high inputs, reduced numbers and volume of insecticidal sprays, number of new insect pests are now claiming *Bt* cotton as their new host. In many parts of the country and the world, *Bt* cotton is under threat due to unusual attack of some insect pests. There are the possibilities of spread of the pests which may make a havoc, if due attention is not being given. In middle Gujarat, the mirid bug and pink bollworm are found as emerging inset pests of *Bt* cotton. The major threat to the continued success of *Bt* crops is evolution of resistance by pests. While most target pest populations remain susceptible, resistance to *Bt* crops has been reported in one of the most devastating pests, the pink bollworm (*Pectinophora gossypiella* Saunders), evolved resistance to transgenic cotton. The pink bollworm had the genetic potential to evolve resistance and was under intense selection for resistance in the field. The pink bollworm said to be rampant through out Vadodara district especially in middle Gujarat. In the present investigation, pink bollworm and mirid bug were found as the emerging pests in *Bt* cotton. The monitoring of pink bollworm resistance was also worked out.

8. A rapid process for preparation of bioenriched compost for cotton stalks - Dr. V. Mageshwaran : He studied the effect of microbial consortia on rapid composting and nutrient level improvement in wet and dry cotton stalks. Good quality compost was prepared at 45 and 60 days from wet and dry cotton stalks using microbial consortia, while the same was obtained at 60 and 90 days respectively without microbial consortia. Thus fifteen and thirty days could be saved for the preparation of compost from wet and dry cotton stalks respectively. The nutrient level of microbial treated compost is better than untreated compost.

9. Enhancement of UV protective property of cotton fabric by using plant extract - Dr. Vandana Gupta : She pointed out that by improving UV protective property of cotton fabric using natural source such as plants can provide safe and healthy life for each member of the society and can increase the value and demand of cotton based textiles. Now a days with more environmental consciousness and more health problems associated with the incidence of skin cancer due to excessive exposure to sunlight as well as the use of synthetic products, consumers are looking for products with additional performance properties, developed through natural sources such as plants. Cotton being the most versatile and one of the favourite fiber for summer, can be treated with *Syzygium cumini* leaves extract which exhibits the potential to enhance its UV protective property thus providing a safe shield from harmful effect of UV radiations not only to outdoor workers but each member of the society when used as apparel.

All the contestants presented their work in a lucid manner with quality presentation of slides.

Concurrent Session VII : Crop Improvement and Crop Production

Chairman : Dr T.C.M. Naidu, Principal Scientist, Regl. Agril. Res. Station, Guntur
Co- chairman : Dr.R.S. Sangwan, Head Cotton, CCS HAU, Hisar
Rapporteurs : Dr.S.Bharathi, Dr. S.Rajamani

Invited Papers

1. Inheritance of resistance against cotton leaf curl virus disease in *G. hirsutum* - Dr. R.S. Sangwan : He reviewed the present situation regarding leaf curl virus diseaseon cotton and due to very high incidence of CLCuD, complete absence of symptoms were noticed even in the resistant genotypes and it indicates that resistance to CLCud was dominant over susceptibility. The possibilities of obtaining resistant reaction by complementary interaction of genes responsible for susceptibility was explored by studying the cross between susceptible and susceptible. Resistance was governed by two dominant genes and exploitation of diploid cottons to impart resistance against CLCuD and proper whitefly management has to be done to overcome the disease.

2. Does *Bt* cotton differ from conventional cotton on agronomic requirement- Dr. K. Sankarnarayanan : He reviewed the research work done in India on *Bt* cotton and emphasized the differences in nutrient management aspects and plant geometry beteen *Bt* and non *Bt* genotypes. The steep increase in adoption of *Bt* hybrids across the country by numerous farmers have proved that the technology is well accepted by Indian farmers. He expressed that the morphological and physiological changes in these introgressed Bt cultivars offer an excellent opportunity for agronomic manipulation.

3. Characterization of bioremediation bacterium from cotton field of Gunupur area Odisha - Dr. Manoj Kumar Das : He concluded that the isolated bacterial strain is a potential biodegrader of carbofuran compound and the further study of this bacterium will help us in establishing phytogenetic relationship among different strains of bacteria in the process of degradation and may further help us in development / transformation of other bacteria to acquire biodegradation process through recombinant DNA technology. The molecular characterization of the plasmid may help in developing certain strains of bacteria for bioremediation of carbomate group of pesticides *per se*. To mitigate the hazardous effects of heavy chemical residues in the soil, use of microorganisms is the cost effective and ecofriendly management option.

Concurrent Session VIII : Crop Protection and Biosafety

Chairman : Dr S.K. Benerjee, Former Principal Scientist, CICR, Nagpur
Co- chairman : Dr. B.L Chopra, Former Senior Cotton Pathologist, PAU, Ludhiana
Rapporteurs : Dr. M. Seshamaha Lakshmi, G. Bindu Madhavi

Invited Papers

1. Secondary pest outbreak in *Bt* cotton- Dr. Rishi Kumar : He mentioned the factors associated with the out break of secondary insect pests such as mired bugs, stinkbugs, mealybugs and other sucking pests in *Bt* cotton crop.The factors are (i) reduction in application of broad spectrum insecticide for target pests(ii) impact on natural enemy populations (iii) reduction in interspecific competition due to the absence of primary / target pest.

2. Status of nematode problems on cotton – An Indian scenario – Dr. K.K. Verma : He explained the prevailing nematode problems, hot spots economic losses their management in detail. He also insisted the need to carry out intensive surveys for recording other economically important phytonematodes associated with cotton. He also mentioned the importance of screening f transgenic plants to nematodes and identification of resistant genes to reniform and root knot nematode in cotton.

3. Increasing trend of bio pesticide in cotton production technologies – Dr. A. G. Sreenivas : He stated that the developing countries have hige possibilities for using bio – pesticides as the production is less expensive and labour saving. He stressed the need of use of bio pesticides in control of different cotton pests in present day explained details of different registered bio pesticides available in India. At the same time, he mentioned the efficacy of microbial activity, survival of micro organisms, delivery systems, determininghost range, avoiding injury to non target organisms, consistant performance under field conditions, economics, Government regulatons and the confidence among the end users have to be taken into consideration for popularizing the bio – pesticides.

Concurrent Session IX : (Crop Improvement, Biotechnology and Post harvest Technology)

Oral Presentations

Chairman : Dr. Pankaj Rathor, Director PAU Regl. Station, Faridkot
Co- chairman : Dr. O. P. Tuteja, Principal Scientist CICR Regl. Station, Sirsa
Rapporteurs : Dr. S. Rajamani and Dr. K. V. Shiva Reddy

1. American cotton genotypre Phuley Yamuna (RHC 0717) Potential for central zone of India - Dr. R. W. Bharud : He indicated that genotype Phule Yamuna RHC (0717) recorded 33.96 per cent and 19.96 per cent higher seed cotton yield than the zonal check and local check, respectively. The RHC 0717 was adjudged as the best entry in the twenty one trials out of thirty trials conducted at different locations in respect to yield and yield attributing characters. Likewise, this variety performed excellent fibre properties. The variety showed disease free reaction to grey mildew, resistant to BLB, moderately resistant to ALB and tolerant to sucking peats and bollworm. Therefore, this genotype is recommended under the name 'Phule Yamuna' for commercial cultivation in irrigated tract of central zone of India comprising Maharashtra, Madhya Pradesh and Gujarat state.

2. Stability for seed cotton yield and its components in cotton (*Gossypium hirsutum* L.) - Dr. Y Rama Reddy : He said that eleven diverse *G.hirsutum* genotypes were evaluated to study their stable performance over the periods for nine characters. The performance of G x E interactions revealed variation was found significant for the characters, bolls/plant, halo length, seed index and seed cotton yield for the characters indicating the seasons wise quite diverse with regard to their effect on the performance of the genotypes for different traits studied. Among the genotypes NDLH 1928 performed stable over environments for the trait, seed cotton yield.

3. Genetic variability studies in *Gossypium* spp for the development of superior fibre quality lines - Dr. N. Kannan : He pointed out that one backcross generation and two modified backcross generations were developed for line development programme. High heritability and high genetic advance were observed for span length and fibre strength in most of the generations of all the three crosses. This indicates the preponderance of additive gene action in the inheritance of this traits and offers the scope for improvement through simple selection procedures. In the present study, long staple with high fibre strength line with *hirsutum* background were obtained in the back cross. Similarly in modified back cross I, long and extra-long staple lines with high fibre strength and in modified backcross II, long and extra-long staple lines with high fibre strength with recurrent plant background were obtained. The fibre quality parameters were assessed.

4. Multivariate analysis of genetic diversity in upland cotton (*Gossypium hirsutum* L.) - Dr. S. Pradeep : He pointed out the genetic divergence was carried out with sixty genotypes of upland cotton based on 15 characters using Mahalanobis' D^2 statistic and principal component analysis. On the basis of D^2 statistic 60 genotypes were grouped into 11 clusters indicating that the genetic diversity and geographical diversity were not related and PCA identified seven principal components in upland cotton. The PCA enabled loading of similar type of variables on a common principal component. Divergence studies indicated that geographical diversity is always not necessarily associated with the genetic diversity. Multivariate analysis revealed maximum divergence and signifying their role in exploitation of heterosis.

5. Genetic analysis in cotton (*Gossypium hirsutum* L.) for mechanical harvesting characters - Dr. P. Karthikeyan : He studied the genetics of plant ideotype characters and to develop superior cotton hybrids suitable for mechanical harvesting. Twenty one crosses obtained by line × tester fashion and their parents were evaluated for 11 biometric traits. Based on mechanical harvesting viewpoint, the desirable features such as earliness, short and compact plant type, absence of monopodial branch, short sympodial branch, synchronous boll bursting, bigger and high weighing bolls, high single plant yield and high ginning per cent with desired fibre quality characters were considered as suitable for developing ideotypes. These selected hybrids further need to be evaluated for their efficacy to defoliant and plant growth regulator applications.

Concurrent Session X : (Crop Production, Mechanization and Economic Development)

Oral Presentations

Chairman : Dr. N. V. Naidu, Director Extension, ANGRAU
Co- chairman : Dr. E. Narayana, ADR, Regl. Agril. Res. Station, Gutnur
Rapporteurs : Dr. S. Ratna Kumari, Dr. K. V. Shiva Reddy and S. Bharati

1. **Staple length composition of production and export of cotton in India - Dr. Devendra Beeraladinni :** He pointed out taht during the last 18 years the production of long staple cotton has increased while the production of short staple cotton has decreased and that of extra long staple (ELS) cotton remained constant. This has witnessed a paradigm shift in export of staple length composition of raw cotton from India. The percentage share of short staple cotton in total raw cotton exports has declined. While the percentage share of long staple cotton in total raw cotton export has increased. But there was no much change in the export share of ELS cotton. However during the same period, the export share of ELS cotton was increased from nil to a mere 1.87 per cent except a share of more than 10 per cent. At present more than 90 per cent of cotton area covered under *Bt* hybrids in India, inadvertently it has led to a surplus production of long staple cotton. In case of short staple and ELS cotton the production is less than the requirement. Hence, India imports ELS and short staple cotton from other countries. Therefore to encourage the production of short staple and ELS cotton in India research efforts should be made to develop *Bt* hybrids (as in long staple cotton) in these fibre length classes.

2. **Poly mulch as moisture conservation technique in ET based drip irrigated *Bt* cotton in vertisols of Andhra Pradesh - Dr. S. Bharathi :** She said taht thee was significant difference in growth, yield contributing characters and seed cotton yield with different treatments tested. The conducive growth environment and microclimate under polyethylene mulching with or without drip on growth components finally reflected in better assimilate partitioning to reproductive structures as evidenced from the production by in producing number of bolls/plant compared to rainfed thus contributing significantly to higher seed cotton yield under poly mulched ET drip irrigation compared to rainfed. Among the treatments 0.6 Epan + polymulching recorded significantly higher seed cotton yield with maximum water and nitrogen use efficiency.

3. **Efficacy of glyphosate and other herbicides in management of weeds in rainfed cotton (*Gossypium hirsutum* L.) under high density planting system - Dr. B. S. Nayak :** He said that among all the weed management treatments weed free check recorded significantly the highest seed cotton yield, bolls/plant, bolls/m and boll weight. This was followed by one hoeing at 20 DAS + Glyphosate @ 1.0 kg/ha, one hoeing at 20 DAS + Glyphosate @ 0.75 kg/ha and one hoeing at 20 DAS + Glyphosate @ 0.50 kg/ha which were *at par*. Therefore, it may be concluded that the integrated method of one hoeing at 20 DAS + post-emergence application of Glyphosate @ 1.0 kg ha^{-1} as directed spray at 40 DAS was the most effective and economic method of weed control in rainfed cotton grown under high density planting system.

4. **Global competitiveness of cotton in Tamil Nadu - Dr. S. Kanaka :** She discussed the combines policy analysis matrix techniques to model the analysis of profitability from cotton cultivation. Policy analysis matrices are computed for a sample of cotton growers located in the dry land of the Tamil Nadu under observed conventional and profit-efficient farming conditions. In this study cotton had been not competitive for most of the period under consideration. EPC estimates showed that it was more than unity like DRC in the most of the study period. However it could be seen that these had been an decreasing trend

in the values of EPC and DRC. Since NPC value are less than unity it indicates that the state had not protected the crop at the farmers level. The estimates of DRC revealed that the state had comparative advantage in cotton export. The main conclusion is that the usefulness of the policy analysis matrix might be substantially enhanced by simulating profitability after efficiency-improving managerial decisions have been adopted.

Concurrent Session XI : (Crop Protection and Biosafety)

Oral Presentations

Chairman : Dr. Joginder Singh, Former HOD Entomology, PAU, Ludhiana
Co- chairman : Dr. Rishi Kumar, Principal Scientist, CICR, Regl. Station, Sirsa
Rapporteurs : Dr. S. L. Bhattiprolu and Dr. Sesha Mahalakshmi

1. **Status of whitefly (*Bemesia tabaci*) population on Bt cotton in Marathwada region of Maharastra under changing climate - Dr. P. R. Zanwar :** He pointed out that on the basis of taluka wise roving survey, the district wise mean data was calculated and showed that maximum incidence of whitefly was recorded in Hingoli followed by Jalna and minimum in Beed. The five years data indicated that the severity of whitefly incidence was more. It is observed that Hingoli and Jalna districts of Marathwada are identified as hotspots for cotton whitefly.

2. **Population dynamics of insect pests in scace rainfall region of Andhra Pradesh - Dr. A. S. R. Sarma :** He concluded that leafhoppers attained two peaks during the season in the test hybrid, DCH 32. The leafhopper population had a significant and positive correlation with temperature minimum and relative humidity (evening) whereas thrips showed a significant and positive correlation with both maximum and minimum temperatures. Moth catches of *H. armigera* had a significant but negative correlation with both maximum and minimum temperatures in one of the years of study and significantandpositive correlation with maximum temperature in the other year of study. Hence, it can be concluded that a long term study can only give complete picture of the dynamics of the insect pests.

3. **Field performance of *Bt* cotton hybrids against major pests under unprotected conditions in Andhra Pradesh - Dr. N. V. V. S. Durga Prasad :** He evaluate 59 *Bt* cotton hybrids along with check hybrid (Jaadoo) against sucking pests. Among the different sucking pests, leafhopper incidence was moderate to high, where as incidence of aphids and whiteflies was low to medium and the thrips incidence was very low. The incidence of American bollworm is very low which was observed for a very short period incidence of pink bollworm and tobacco caterpillar was nil during the crop growth period. The hybrid, Surpass Asha recorded lowest incidence of whiteflies and the highest incidence of whiteflies was recorded in the hybrid, Ankur 2595.

Session XII : Poster Presentation

Judges : Dr. O. P. Tuteja, Dr. B. G. Solanki, Dr. Joginder Singh,
Dr. B. L. Chopra and Dr. P. Nalyani

The poster presentation was assessed by a panel of judges from different disciplines and places namely Dr. O. P. Tuteja, Principal Scientist, Breeding, CICR Regl. Station, Sirsa; Dr. B. G. Solanki, Head Cotton, NAU Main Cotton Research Station, Surat; Dr. Joginder Singh, Former HOD, Entomology, PAU, Ludhiana; Dr. B. L. Chopra, Former Sr. Cotton Pathologist, PAU, Ludhiana and Dr. P. Nalayini, Principal Scientist, Agronomy CICR, Regl. Station, Coimbatore. A total 122 posters were evaluated (Crop Improvement, Biotechnology and Post harvest technology-43), (Crop Production, Mechanization and Economic Development-38) and (Crop Protection and Bio-safety-41). The committee critically gone through these posters and discussed the quarries/clarification from the presentors. All the poster beautifully depicted the bindings through tables, graphs and photographs.

Saturday, December 19, 2015

Session XIII : Lead Papers

Chairman : Dr. B. Rosaiah, Ex-ADR, RARS, Lam

Co chairman : Dr T.C.M. Naidu, Principal Scientist (Physiology), RARS, Lam

Rapporteur : Dr. M. Sesha Mahalakshmi, Scientist (Ento), RARS, Lam

1. **Cotton and its prospective uses – Dr. Vandana Gupta :** She stressed upon the use of cotton fabric with improved quality by different methods for development of functional finishes, methods to improve temperature and moisture management and water repellency in cotton fabric through phase change technology. Also enlighted about the different types of available modified cotton fabrics

2. **India's global leadership in cotton – How to sustain the success – Dr. S. Ganeshan :** He highlighted the changing scenario of cotton production and consumption in the world. He stressed upon the measures to be taken to increase the cotton consumption and use of cotton fabric among the people through government policies and decisions.

3. **Cotton cultivation – Future solutions – Dr. Rajasekharan :** He highlighted the current concerns in cotton in India and about forthcoming products from Dow agro sciences such as Delegate and Isoclast.

Invited Papers

1. **Mechanization of cotton harvesting in India – Status, issues and challenges – Dr. S.K.Shukla :** He emphasized the necessity, issues and challenges of mechanization, varital and physiological requirements of hybrids for suitability of mechanical picking and also pros and cons of mechanization in cotton.

2. **Development of GIS and GPS based spatial cotton fibre quality map – Dr. V.G.Arude :** He delivered a lecture about the fibre quality traits, issues and methodology for mapping based on GIS & GPS. Dissemination of location specific information related to fibre quality to the end users is very easy and quick through fibre quality maps.

Session XIV : Open House Discussion

Chairman : Dr. K. S. Khokhar, Vice Chancellor, CCS HAU, Hisar

Co chairman : Dr. N. Gopalakrishnan, Former ADG (CC) ICAR, New Delhi

Rapporteur : Dr. S. L. Bhattiprolu and Dr. Sesha Mahalakshmi

Whitefly outbreak – Reasons and Management

Pink bollworm – Becoming threat to cotton cultivation

Leaf curl virus disease – Problematic in *Bt* cotton hybrids

Stability in Cotton production – How to sustain

Pannelists : Dr. S. S. Siwach, Dr. Joginder Singh, Dr. D. Monga, Dr. Raja Sekharan, Dr. Rishi Kumar, Dr. Asif Tanwer and Dr. China Babu Naiak.

Dr. S. S. Siwach spoke on the behaviour of varietal status on there problems. He also pointed out that *Bt* hybrids of any company are highly suspectable to CLCuD. Regarding production behaviour he said that due climatic shift the production and productivity.

Dr. Joginder Singh, Dr. Rishi Kumar and Dr. China Babu Naik gave the details of the reasons of Whitefly outbreak and pointed that prolonged dry spells, poor distribution of rainfall and high day temperatures were the main factors responsible for the outbreak. They have also said that multiplicity of *Bt* hybrids, cultivation of *Bt* hybrids unsuitable due to leaf curl and whitefly. Some other reasons were described by thems namly, late sowing, more use of fertilizers unbalanced use of urea, use of spurious phytoharmous exposure the crop to water stress.

Dr. Asif Tanweer and Dr. Rajashekharan also highlighted the current problems and propects of over coming to them. They also pointed out that broad spectrum insecticides in the early season be used. They also disapproved the tank mix leves and making cocktail chemicals, also repeated sprays of same group of insecticides. Use of higher closes of pesticides and mismanagement of insecticide use.

Valedictory and Closing Function

Chairman : Dr. K. S. Khokhar, Honourable Vice Chancellor, CCS HAU, Hisar

Co chairman : Dr. N. Gopalakrishnan, Former ADG (CC) ICAR, New Delhi

Rapporteur : Dr. M. S. Chauhan, Secretary, CRDA and Senior Pathologist Cotton, CCS HAU, Hisar

Dr. V. Chenga Reddy, Principal Scientist cum Organizing Secretary, Symposium

At the outset, Dr. R. S. Sangwan welcomed the dignitaries to the dais. The meeting started with the presidential remarks of Dr. N. Gopalakrishnan, Principal Scientist (Biochemistry), CICR, Coimbatore. Dr. S. S. Siwach, Vice President, CRDA, Hisar, Dr. Monga, Head, CICR RS, Sirsa, Dr.

Joginder Singh, Entomologist, Retd. and Dr. P. Rajasekhar, Registrar, Acharya Nagarjuna University addressed the gathering. Later, the proceedings of Crop Improvement was presnted by Dr. B. Govinda Rao, Principal Scientist (Breeding), Crop Production by Dr. S. Ratna Kumari, Principal Scientist (Crop Physiology) and Crop Protection by Dr. N. V. V. S. D. Prasad were presented. Then, the chief guest Dr. K. S. Khokhar, Hon,ble Vice Chancellor, CCSHAU, Hisar thanked the ANGRAU Vice chancellor, Director of Research and Dr. V. Chenga Reddy and his team for beautiful organization of the symposium. Then he presented young scientist Award and also best Poster presentation Awards in different disciplines to the winners and to the cotton scientists of RARS, Guntur namely Dr. V. Chenga Reddy, Dr. K. V. Siva Reddy, Dr. S. Ratna Kumari, Dr. S. Bharathi, Dr. N. V. V. S. Durga Prasad, Dr. M. Seshalakshmi, Dr. B. Sreelakshmi, Dr. Y. Rama Reddy, Dr Y Satish, Dr. S. V. Reddy and also from CCS HAU, Hisar namely Dr. R. S. Sangwan, Dr. Ominder Sangwan, Dr. S. R. Pundir, Dr. S. Nimbal, Dr. Shiwani Mandhania, Dr. Neha Wadhwa, Dr. Ashish Jain Miss Sonika were presented the momento by the Chief Guest.

Later, Dr. N. Gopalakrishan praised the CRDA team and the ANGRAU Cotton team for nice organization of the Seminar and also advised the research workers to concentrate both on basic and applied research to promote cotton and also to make the cotton crop remunerative.

Dr. V. Chenga Reddy, Organising Secretary, National Symposium proposed formal vote of thanks, in which he thanked the ICAR, CRDA and ANGRAU for giving the opportunity to conducting the National Seminar in Guntur. He also thanked all the participants for presenting good research papers and the interaction as and when necessary. He also thanked the Acharya nagarjuna University officials for providing venue for the Seminar. Finally, he thanked all the people who involved directly or indirectly in the seminar.

Young Scientist Award

Ritu Raj : P.S. Sekhon, M.K. Sangha and Dharminder Pathak Department of Plant Pathology, Punjab Agricultural University, Ludhiana

Title : Jamonic acid and salicyclic acid induced protection against cotton leaf curl disease

Best Poster Award

Crop Improvement, Biotechnology and Post Harvest Technology

Suruchi Vij, M.S. Gill Dharminder Pathak and Navraj Kaur

Department of Palnt Breeding and Genetics, Punjab Agricultural University, Ludhiana

Title : Interspecific hybridization between *Gossypium hirsutum* and *Gossypium arboreum*

Crop Production and Mechanization

S.M. Wasnik and K.R. Kranthi

Central Institute for Cotton Research, Nagpur

Title : E-Kapas - An Innovative ICT Model of CICR in Cotton Information Delivery

Crop Protection and Biosafety

V. Chinna Babu Naik, A. Ashwini, J.G. Mehar, S. Kumbhare, S. Kranthi and M.V. Venugopalan

Central Institute for Cotton Research, Nagpur

Title : Impact of new molecules on bollworm management in cotton under high density planting system

The Seminar ended with the "National Anthem".

Specific Recommendations made during the International Symposium

- Most of the *Bt* cotton hybrids developed are in long fibre range, while few or none are in medium, medium long or short fibre length types. Work will have to be initiated to remove this anomaly in development of *Bt* cotton.
- Consistent improvement in fibre quality parameters keeping in view the industry requirement is needed. Fibre quality parameters that need improvement are higher tenacity, less short fibre content and improvement in fibre elongation.
- Concept of community refugia suggested to tackle problem of insect resistance. Need to work on boll specific promoters so as to maintain toxin protein expression at least till 150 days.
- New novel toxin proteins for resources other than *Bacillus thuringiensis* need to be explored to serve as alternate to *Bt*.
- Molecular markers are required to be used profusely for speeding up speeding work for tolerance to stress.
- Revision and recasting of concept and strategies of *Bt* cotton refugia : it may include the following components.
  a) Promotion of non cotton refugia
  b) Concerted efforts for early replacement of BG I version of *Bt* cotton by BG II *Bt* cotton.
  c) Growing of different versions of *Bt* genes so as to delay resistance.
- Each private seed company should restrict release of *Bt* cotton hybrids to 2-3 with acceptable field performance and also mention the pedigree of their released *Bt* hybrid.
- Improving the level of resistance to biotic and abiotic stresses.
- Enhanced water use efficiency, nurtient use efficiency and profits by the adoption of multitier cropping.
- Need for good quality water for pre sowing irrigation for maintaing the required plant stand and enhancing the yield of cotton.
- Strictly avoid synthtic pyrethroids, acephte or insecticide mixtures
- Avoid excessive use of nitrogenous fertilizers *i.e.* urea
- Use yellow sticky traps.
- Use diferithiuron, Buprofezin, Pyriproxyfen, spiromesifen for whitefly management
- Use of host plant resistant varieties or hybrids
- Step up the minimum support price
- Intensive to farmers growing *Gossypium arboreum*
- Setting up and strengthening of value addition facilities.
- Promote long linted spinnable varieties amenable to surgical purpose.
- Ensure timely availability of short duration, compact, non shedding, genotypes of *G. arborium* and timely sowing
- Promote cultivation of *G. arboreum* in High Density Planting system (HDPS)
- Promote the use of authentic neem formulations during early part of season.
- Set up Demonstration Plot in each district of misuse of insecticides to rational insecticide use.
- Subsidise authentic *neem* formulations
- Do not promote the use of monocrotophase
- Clean cultivation leads to fields whitefly free.
- List out insecticides that are permitted for use in cotton
- Promote the concept of conservation biological control
- Use of plain soap water when population are just about to build up.

List of Lead, Invited and Selected Speakers

1. Dr. A. Padma Raju - Honourable Vice-Chancellor, ANGRAU, Hyderabad
2. Dr. K.S. Khokhar - Honourable Vice-Chancellor, CCS HAU, Hisar
3. Dr. K.R.S. Sambasiva Rao - Rector, ANU, Guntur
4. Dr. K. Raja Reddy, Director of Research, ANGRAU, Hyderabad
5. Dr. N.V. Naidu, Director of Extension Education, ANGRAU, Hyderabad
6. Dr. T. Ramesh Babu, Dean, Agriculture, ANGRAU, Hyderabad
7. Dr. Neeraja, Dean, Home Science, ANGRAU, Hyderabad
8. Dr. S.S. Siwach, Director of Research, CCS HAU, Hisar
9. Dr. A. Ramasami, CMD, Rasi Seeds, Attur
10. Dr. K. Rosaiah, Former ADR, RARS, Guntur
11. Dr. E. Narayana, ADR, RARS, Guntur
12. Dr. N. Gopalakrishnan, Former ADG (CC) ICAR, New Delhi
13. Dr. G. Rosaiah, HOD, Deptt. Microbioloty, ANU, Guntur
14. Dr. H.V.S. Chauhan, Vice President, Indofil Industries, Mumbai
15. Dr. Vipin S. Dagaonkar, Lead Cotton Breeder, Bayer Crop Science, Hyderabad
16. Dr. Pankaj Rathor, Director PAU Regl. Station, Faridkot
    Dr. D. Monga, Head, CICR, Regl. Station, Sirsa
17. Dr. O.P. Tuteja, Principal Scientist, CICR, Regl. Station, Sirsa
18. Dr. R.S. Sangwan, Head Cotton, CCS HAU, Hisar
19. Dr. A. Sarada Devi, Emertis Scientist, ANGRAU, Hyderabad
20. Dr. V. G. Arude, Scientist, CIRCOT, Nagpur
21. Dr. P. Nalayini, Principal Scientist, CICR Regl. Station, Coimbatore
22. Dr. K. Sankarnayanan, Scientist, CICR Regl. Station, Coimbatore
23. Dr. Manoj Kumar Das, Scientist, Odisha
24. Dr. S.K. Shukla, Scientist, CIRCOT, Nagpur
25. Dr. Rishi Kumar, Sr. Scientist, Entomology, CICR Regl. Station, Sirsa
26. Dr. S.V. Reddy, Principal Scientist, RARS, Guntur
27. Dr. A.G. Sreenivas, Sr. Scientist, UAS, Raichur
28. Dr. K.K. Verma, Professor Nematology, CCS HAU, Hisar
29. Dr. B.G. Solanki, Head Cotton, NAU MCRS, Surat
30. Dr. A. Manivannan, Scientist, CICR Regl. Station, Coimbatore
31. Dr. R.W. Bharud, Head Cotton, MPKV, Rahuri
32. Dr. K.V. Siva Reddy, Scientist, RARS, Guntur
33. Dr. V. Rama Reddy, Scientist, RARS, Nandyal
34. Dr. S. Rajamani, Sr. Scientist, RARS, Guntur
35. Dr. V.N. Chinchan, Head Cotton, VNMKV, Parbhani
36. Dr. S. Pradeep, Asstt. Scientist, COA, Bapatla
37. Dr. N. Kannan, Scientist, Annamalai University, Chidambaram

38. Dr. P. Karthikeyan, Scientist, TNAU, Coimbatore
39. Dr. S. Jattar Basha, Scientist, RARS, Nandyal
40. Dr. A.D. Pandgale, Scientist, VNMKV, CRS, Nanded
41. Dr. S. Ratna Kumari, Principal Scientist, RARS, Guntur
42. Dr. S. Bharathi, Scientist, RARS, Guntur
43. Dr. Vinayak Hosamani, Scientist, UAS, COA, Raichur
44. Dr. Kusum Rana, Scientist, CCS HAU, Hisar
45. Dr. Devendra Beeraladinni, Sr. Scientist, UAS, Raichur
46. Dr. S. Kanaka, Scientist, COA, Killikulam
47. Dr. U.B. Hole, Sr. Scientist, MPKV, Rahuri
48. Dr. A.S.R. Sarma, Sr. Scientist, RARS, Nadyal
49. Dr. P.W. Nemade, Scientist, Dr. PDKV, Akola
50. Dr. P.R. Zanwar, Scientist, VNMKV, Parbhani
51. Dr. N.V.V.S. Durga Prasad, Sr. Scientist, RARS, Guntur
52. Dr. S.L. Bhattiprolu, Sr. Scientist, RARS, Guntur
53. Dr. J.D. Deshmukh, Asstt. Prof., VNMKV, Parbhani
54. Dr. H.G. Kencharaddi, Asstt. Scientist, UAS, Dharwad
55. Dr. Anuradha Godara, RA, CCS HAU, Hisar
56. Dr. G.N. Hosagoudar, Asstt. Scientist, AHRS, Ponnampet
57. Miss Rituraj, Ph.D. Scholar, PAU, Ludhiana
58. Dr. S.N. Nandini, Plant Protection Officer, TNAU, Coimbatore
59. Dr. M.B. Zala, Scientist, AAU, ARS, Sansoli
60. Dr. V. Mageshwaran, Scientist, CIRCOT, Mumbai
61. Dr. Vandana Gupta, RA, CCS HAU, Hisar

AUTHOR INDEX