National Symposium

on

"Cotton Production Technologies in the Next Decade : Problems and Perspectives"

at

Odisha University of Agriculture and Technology

Bhubaneswar, Odisha - 751 003

22-24 January, 2020

PROCEEDINGS

Jointly Organised by

Cotton Research and Development Association (CRDA)
CCS Haryana Agricultural University, Hisar - 125 004

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Complied and Edited by :-
Dr. M. S. Chauhan
Dr. R. K. Saini
Dr. Man Mohan
Dr. Ashish Jain

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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 artifial 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 cultivates 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.

The Symposium would give the scientists, experts and officials working in the region a platform to share their ideas with experts from other parts of the country which would be helpful in developing a strategy for the fibre crop development in the region.

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/-

S. S. Siwach

President, Cotton Research and Development Association

CCS Haryana Agricultural University, Hisar

Place : Bhubaneswar, Odisha

Dated : 22-01-2020

PREFACE

Cotton is one of the most ancient and very important commercial crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It is cultivated for domestic consumption and also exported in about 111 countries worldwide and hence called **"King of Fibres"** or **"White Gold"**. 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 in the vast diverted agro-climatic situations. Cotton is basically cultivated for its fibre which is used as textile raw material. It is cultivated from Punjab in the north to Kanyakumari in the south and Assam in the east to Kutch (Gujarat) in the west.

India, the second largest producer, consumer as well as exporters of cotton next to China with 34 per cent of world area and 21 per cent of world production and continue to maintain the largest area under cotton. Within a span of fifteen years, the cotton production in the country has gone more than double with the increase of the productivity. The productivity of cotton has not made headway because of more than 70 per cent area is under rainfed cultivation and appearance of new diseases and insect pests in transgenic cotton. However, new emerging threats in terms of biotic and abiotic factors are to be understood properly and effective strategies need to be evolved for their proper redressal. The problems and prospects of *Bt* cottons in the country need to be put in a proper perspective. Therefore, there is an urgent need to properly understand the IPR issues in the best interest of farmers and scientists.

In order to maintain pace with the increased demand for the commodity, both in national and international market, it is imperative to give impetus for development of new cotton and fibre crops varieties and hybrids with appropriate cultivation technologies. Introduction of large number of private sector *Bt* cotton hybrids have brought a welcome change in recent times as far as production gains are concerned. However, to meet the ever increasing demand both in the domestic and international markets, an effective strategy needs to be developed.

The research papers included in the **"Compendium of Lead and Invited Papers"** are related to **"Crop Improvement, Biotechnology and Post Harvest Technology; Crop Production and Mechanization; Crop Protection and Biosafety"** which were the theme areas of the symposium. Present compilation on **"Cotton Production and Technologies in the Next Decade : Problems and Perspective"** is a compendium of holistic advancements and other relevant information related to cotton and other fibre crops covering different disciplines. We hope that the information contained in this **"Compendium of Lead and Invited Papers"** 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 **"Compendium of Lead and Invited Papers"**. We are thankful to the authors of individual chapters/papers for their contribution, time and diligence without which this volume would not have been possible.

We deem it a rare privilege to place on record our sincere gratitude to Dr. S. S. Siwah, Former Director of Research, CCS Haryana Agricultural University, Hisar and President, CRDA for his valuable guidance and directions in the general functioning of CRDA. We take this opportunity to thank all concerned and hope this **Proceeding of National Symposium on "Cotton Production Technologies in the Next Decade : Problems and Perspectives"** will serves the purpose of cotton research workers for furthering the cause of cotton farmers.

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Bhubaneswar - 751 003 (Odisha)

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Editors
Dr. M. S. Chauhan
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Targeted approach through molecular breeding in cotton for increasing productivity in cotton

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Present Scenario : Selection or hybridization program to develop variety/hybrid is the essence of Plant breeding, Phenotype based selection is deceiving due to involvement of non-heritable genetic components and environmental effects. In order to truly predict genotypic values and put them to breeding programs there is a need to understand underlying genetic mechanism and apply them based on the changing climatic and human needs. In 70 years of dedicated efforts of independent India for cotton improvement there is drastic improvement of cotton yields, However from 1947- 2002 the yield improvement was sluggish and it took 55 years to double the yields but targeted improvement activities like *Bt* cotton introduction bought double yield level *i.e.,* 207kg/ha to 324kg/ha within a year of introduction. It is one of the successful story of targeted improvements in cotton. Although cotton breeding in India has seen so many improvement, still there is a huge scope for yield enhancement as Indian productivity of 541 kg/ha is lower than world average (603kg/ha), countries like Australia and Brazil (1737, 1561 kg/ha respectively) have triple yield levels than India which enjoy congenial climatic conditions for cotton growth (Anonymous, 2018). The factors such as weeds, drought and sucking pests can bring upto 56, 33 and 30 per cent yield reduction respectively which can be addressed. India is leading producer of cotton in world by virtue of larger acreage and we export of medium and long staple cotton to other countries, but India also imports Extra-long staple cotton, it was around 5 lakh bales of 170kg during 2006-2007 and it has increased up to 30.945 lakh bales in year 2016-2017 this trend would further increase unless the issue is addressed (Anonymous, 2018). The genomic resources developed or developing in cotton has all the capacity for avoiding such a losses and bring our yield and quality levels on par with other countries. So here we address the techniques and resources specific to cotton for targeted enhancement.

Approaches for targeted molecular breeding : Utilization of Structural genomics, functional genomics, proteomics, and metabolomics approaches coupled with molecular marker assisted breeding and transgenic technology have made significant contributions in enhancing the efficiency of cotton breeding and such methods are collectively referred as molecular breeding. These technologies have huge potential to bring yield levels of India on par with other countries.

a. Genome and transcriptome sequencing : A fully sequenced genome provides useful tools for the breeders, as it allows the discovery of genes, determining their position and function, as well as the development of large marker collections and high resolution maps. With the advancement of NGS technology, reference genome of A and D sub genomes were developed as early as 2014 (Wang *et al.*, 2012; Paterson *et al.*, 2012; Li *et al.*, 2014). In the year 2015,*G. hirsutum* and *G. barbadense* reference genomes have been sequenced (Zhang *et al.*, 2015; Li *et al.*, 2015; Liu *et al.*, 2015; Yuan *et al.*, 2015), reference genome were further improved for their accuracy and are made available for researchers (Hu *et al.,* 2019; Wang *et al.*, 2019; Udall *et al.*, 2019) To assist introgression from wild species, the genomes of *G. turneri* (caducous bracts, insect resistance, and abiotic stress tolerance) (Udall *et al.*, 2019)and *G. kirki* genome are also been sequenced. Transcriptome sequencing helps us to visualize great complexity of plant transcriptomeallowing the identification of rare transcript variants that are being used to improve gene annotation and our knowledge of gene function and regulation. Many comparative expression studies for fiber quality and abiotic stress are published(Hande *et al.*, 2017;Padmalatha *et al.*, 2012b;Padmalatha *et al.*, 2012a; Bowman *et al.*, 2013).However only one dedicated transcriptome sequencing is available for researcher for various tissue i.e. Fiber time series, ovule time series, seed germination time series, stress (cold, hot, salt and PEG treatment time series), Leaf, stamen, pistil, petal, root, thalamus and calycle (calyx) by (Paterson *et al.*, 2012). All the reference and transcriptomegenomes are deposited and made available for researcher through dedicated cotton database "CottonGen"(Yu *et al.*, 2013)and Cotton functional genomics database (Zhu *et al.*, 2017). Although reference genomes are made available, further massive re-sequencing and gene expression studies are essential to identify the key genes responsible for a desired trait and to find its allele variability.

b. Marker discovery : In cotton, there are different marker technologies available i.e., RFLPs, RAPDs, AFLPs, ISSRs, SSRs, TRAP and SRAP, each marker have its own advantage and disadvantages. But in the era sequencing, availability of reference genome is boon to cotton researchers as large number of SNPs are identified using whole genome re-sequencing and transcriptome sequencing. The advancement in reduced representation sequencing methods like Genotype by sequencing (GBS) and Specific-locus amplified fragment sequencing (SLAF) provide scope for highthroughput genotyping. To date in CottonGen 459,826 SNP markers are available for researchers for various studies.

c. Mapping quantitative traits : The quantitative trait loci identification basically helps in finding association between marker and measurable phenotype at genomic level or understanding genetics of traits under study. Bi-Parental Mapping is one of the common methodology which can be successfully employed for identifying QTLs in cotton for various traits.Genome wide association study is also used for developing highly saturated maps in cotton germplasm. This technique allows detecting association among various markers and traits through assessing of the genetic diversity of required traits. Linkage disequilibrium based mapping (LD mapping) is the advanced tool to study complex traits governed by many genes. In cotton, the construction of linkage maps and detection of QTLs for various economic traits has been in progress since 1994 with the first RFLP linkage map (Reinisch *et al.,* 1994), many maps have been constructed(Lacape *et al.*, 2009; Kumar *et al.*, 2019; Ramesh *et al.*, 2019; Sankeshwar *et al.*, 2018; Zhang *et al.,* 2017; Handi *et al.*, 2017). Currently there are around 112 linkage maps and 114 seed cotton yield/lint yield QTLs, 345 lint per cent/ginning outturnQTLs and 2440 fiber QTLs were identified.Bi-parental mapping/ GWASare documented in CottonGen database. Efforts are made to develop linkage maps in wild species like *G.nelsonii* x *G. austral(*Brubaker and Brown 2003), *G. hirsutum* x *G. anomalum* (Brubaker *et al.*, 1999), G. *hirsutum* x *G. mustelinum (Wang et al., 2017)* and G*. hirsutum* x *G. tomentosum* (Keerio et al., 2018). QTLs after validation can be used for marker assisted selection, however transfer of QTL /pyramiding of QTLs is one way of realizing targeted trait introgression (Mekonnen *et al.*, 2017; Guo *et al.*, 2005)or these can be utilized for fine mapping

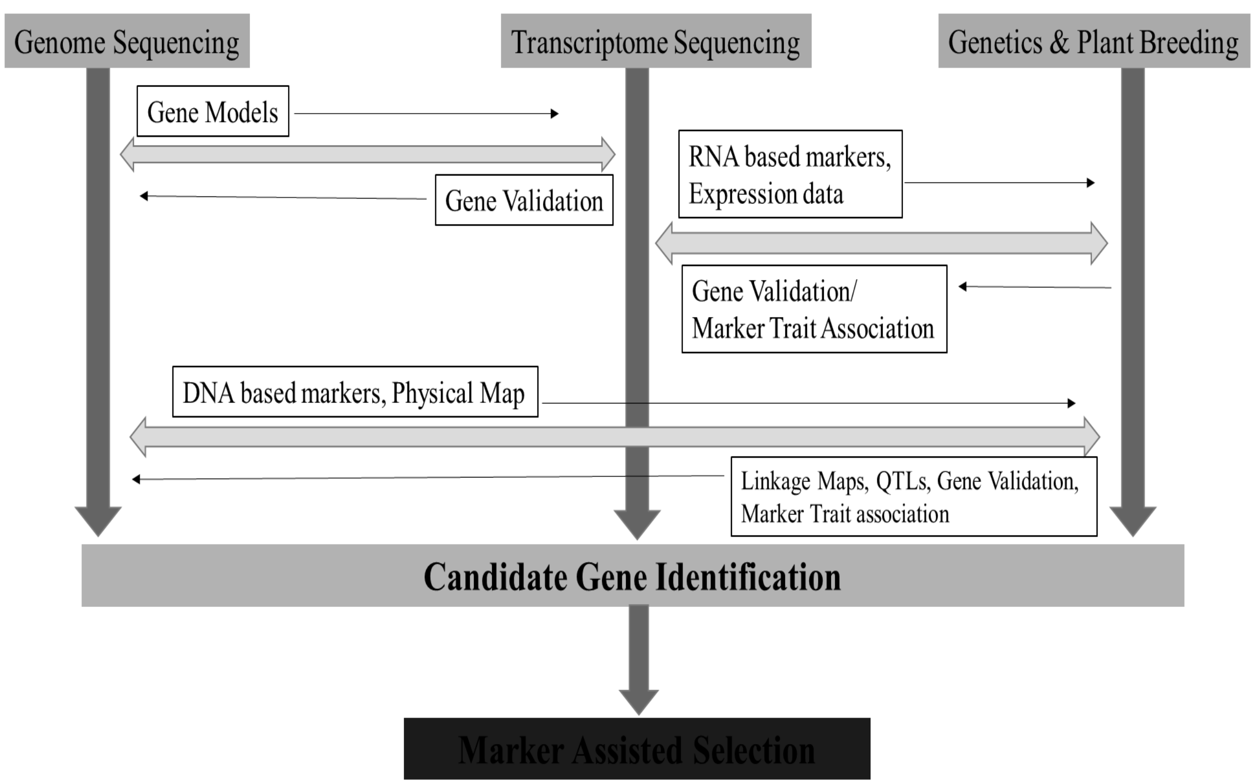

Fig.1 Interdependence of sequencing technologies& plant breeders for understanding genetics of traits.

and map based cloning prior to marker assisted selection.

d. Genetic transformation in cotton : Over the years, plant breeders have improved cotton via conventional breeding methods, but these methods are time-consuming. To complement classical breeding and, at times, reduce the time necessary for new cultivar development, breeders have turned to in vitro plant transformation or genetic engineering, relying mostly on Agrobacterium-mediated transformation technique. Since its adoption in the 1990s, transgenic technology continues to have a tremendous impact on cotton production throughout the world. Currently, genetically modified cottons, in particular insect and herbicide tolerant cotton, account for over 90 and 80 per cent of cultivated cotton acreage all over the world respectively. However, efforts in the development of transgenic cotton are hampered by the recalcitrance of most cotton cultivars, particularly the elite cultivars, to regenerate via tissue culture, a step very often necessary for the transformation process. In vitro regeneration of cotton, in particular regeneration via somatic embryogenesis, is highly genotype dependent. In addition, other factors including explant type, composition and type of media (liquid vs. solid) as well as environmental conditions surrounding the cultures affect the in vitro regeneration of cotton.

Somatic embryogenesis resulting in regeneration of whole plant is an important prerequisite in any plant transformation scheme. The ideal transformation scheme is the one done via somatic embryogenesis because from callus cultures each transformed cell has the potential to produce a plant. The first report of regeneration of *G. hirsutum* (accession Coker-310) was by (Davidonis and Hamilton 1983) who used polyploidcotyledonary tissue. The regeneration via somatic embryogenesis of plants in Gossypium species remains highly genotype dependent as demonstrated by (Trolinder and Xhixian 1989) who screened the 38 genotypes of *G. hirsutum*, *G. barbadense* and *G. arboreum* using various growth regulator combinations and found that Coker-312 had the highest frequency of somatic embryos, followed by Coker-304, Coker-315, T-25 and Coker-310. Most of the successful regeneration and transformation studies have utilized Coker-312 for somatic embryogenesis. (Sangannavar *et al.*, 2012)developed the efficient in vitro regeneration and plant establishment in Coker-312. The creation of transgenic plants especially involves invitro culturing of an appropriate plant tissue and regeneration into a fertile plant. Regeneration of plants from invitro cultured tissues can results in genetic variation among regenerated plants.

At the beginning, the two major goals of genetic engineering in cotton were to confer insect resistance and tolerance to more environmentally acceptable herbicides (John and Stewart 1992). Insect resistance, herbicide resistance, environmental stress, and hybrid cotton development are topics related to cotton management, and each one has an indirect effect on the quality and quantity of fiber produced. However, none of them directly modifies the quality of fiber, which is a quantitative trait. Recently, however, efforts have been made through genetic engineering to enhance cotton fiber quality (Chen and Burke

2015). Regardless of the goal, a dependable regeneration system is a prerequisite for an efficient plant transformation scheme. It is noteworthy that cotton transformation, both by Agrobacterium or biolistic method, is most often not a limiting factor (Rajasekaran 2013), but identification of embryogenic cells and regeneration of plantlets is necessary in order to achieve success. A cotton variant was obtained using antisense technology against (+)-delta-cadinene gene to suppress terpenoid aldehydes (gossypol) but with lysigenous glands (Benedict *et al.,* 2004). RNAi-knockdown of delta-cadinene synthase gene(s) was used to engineer plants that produced ultra-low gossypol cottonseed (ULGCS) (Rathore *et al.*, 2012). Recently ultra-low gossypol cotton seed (ULGCS) were obtained by using PTGS and seed-specific promoter (á-globulin) through suppression of CDN genes and these lines are under field evaluations (Sunilkumar *et al.,* 2006; Palle *et al.*, 2013).

e. Genome editing in cotton : Plant breeding based on phenotypic selection or different forms of MAS (backcrossing, recurrent selection, F_2 enrichment and genomic selection) relies on genetic variability created through natural mutations/induced mutations and/or reshuffled gene combinations driven by controlled crossing. The genetic variability so created is a result of genome wide changes in gene combinations attributable to randomness of mutagenic and crossover events. Even plant breeding based on genetic engineering relies on random insertion of desired genes across taxonomic borders. Thus, phenotype and marker –based selections and genetic engineering are less precise. However, gene editing using several classes of nucleases, especially those of CRISPR –Cas9 is more precise than either MAS or genetic engineering. Gene editing modifies only the existing /native target gene sequence and therefore is considered as a safe tool for generating genetic variability and selection of desired phenotype. Hence, the products in terms of varieties developed using gene editing tools are not expected to be associated with laborious and expensive regulatory processes as is in vogue with respect to transgenic varieties.

CRISPR/Cas9 mainly utilizes single guide RNA (sgRNA) to direct cleavage of the target DNA by the Cas9 protein, which generates double-stranded breaks (DSBs) at the target site that are usually repaired through non-homologous end joining (NHEJ), an error-prone mechanism causing mutations in the target site(Mahfouz *et al.*, 2011; Cong *et al.*, 2013; Mali *et al.*, 2013). Several studies have also investigated the feasibilities of the use of CRISPR/Cas9 in cotton (*Gossypium hirsutum*), an allotetraploid species with a large genome (~2.5 Gb) (Li *et al.*, 2015; Zhang *et al.*, 2015). These studies demonstrated a moderate to very high editing efficiency of CRISPR/Cas9 for both exogenous marker genes(Janga *et al.*, 2017; Zhu *et al.*, 2018)and endogenous genes in cotton (Chen *et al.,* 2017; Gao *et al.*, 2017; Li *et al.*, 2017). Successful use of CRISPR/Cas9 in cotton still relies on Agrobacterium-mediated transformation and tissue culture, a genotype-dependent and low efficiency process, but it provides a powerful tool for cotton functional genomics as CRISPR/Cas9 seems to be more efficient than RNA interference (RNAi) and virus induced gene silencing (VIGS) in terms of knocking out the function of target genes (Gao *et al.,* 2017). CRISPR/Cas9 has been used to edit a couple of agronomically important cotton genes, such as MYB25-like(Li *et al.*, 2017) and a gene encoding arginase (ARG) (Yanling *et al.*, 2017). CRISPR/Cas9 knockout of GoPGF (synonym CGF3) genes resulted in glandless phenotype in cotton (Janga *et al.*, 2019). (Katageri *et al.*, 2019) is presently working on 'Application of CRISPR Cas9 system to develop gossypol free seed in upland cotton'. But it is necessary to further develop an efficient gene editing system for molecular biology studies that can be easily adopted by any laboratory with basic facilities and to use more cotton genes with potential breeding value in gene editing studies.

Future prospects : Although new assemblies with much higher precision are available lately, much of the functional genomic work to characterize gene function is yet to be carried. With advent of GBS technology many high density maps have also been published, however work on fine mapping and map based cloning has been barely carried. There is a need for development of efficient genetic transformation system in order to improve the gene transfer and gene editing techniques which have potential breeding applications. In conclusion, with usage of the above mentioned molecular breeding approaches there is huge possibility to realize targeted aim of cotton breeders in developing climate smart genotypes with high yield and fine quality.

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Fibre quality improvement - Indian perspective

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Cotton, the white gold, is eco friendly and have comfort characteristics and hence cultivated mainly for its textile fibre apart from other uses for extraction of seed oil, seeds as well as oil cakes for animal feed etc. Since Independence, there was a drastic change in both quality and quantity of cotton production in India (Tables 1 and 2). The production increased from 2.3 million bales in 1947-1948 to 36.1 million bales in 2018-2019. At the time of independence, mostly short and medium staple cottons were produced. Today, India produces the widest range of cottons from 6^s to 120^s counts, from non-spinnable coarse to medium, long, extra long and superfine cotton.

Currently, the long and extra long staple cotton production is more than 75 per cent of total cotton production, which was only 17 per cent before establishment of AICRP on Cotton in the country. This is mainly due to the concerted efforts of cotton breeders who developed high yielding long and extra long staple cotton varieties and hybrids suitable to different agro ecosystem of the country. The cotton productivity has been enhanced remarkably especially after the establishment of AICRP on Cotton. The productivity has been increased from 90 kg lint/ha during 1947-1948 to as high as 565 kg/ha during 2013-2014.

Ideally the textile mills look for suitable combination of staple length, micronaire and strength for spinning yarn of appropriate quality. With the establishment of AICRP on Cotton during the year 1967, more emphasis was given to the improvement of yield as well as quality in cotton, which led to the quantum increase in the production of long and extra long staple cotton in India. A brief account of some of the important milestones in fibre quality improvement in cotton is furnished below.

1967: All India Coordinated Cotton Improvement Project was established with head quarter at Coimbatore and all

Table 1. Quantitative change in area and production of cotton in India

Period	Area (million ha)	Production (million each) bales of 170 kg
1947-1948	4.3	2.3
1966-1967 (start of AICRP on Cotton)	7.8	5.3
2018-2019	12.2	36.1

Table 2. Qualitative change in production of three staple length group of cotton

Period	Production in Million bales (170 kg each)			
	Long and Extra long	Medium	Short	**Total**
1947-1948	—	1.53 (67)	0.76 (33)	**2.29**
1961-1966	0.92 (17)	3.70 (68)	0.82 (15)	**5.44**
2016-1917	27.03 (77)	7.02 (20)	1.05 (3)	**35.10**

(Figures in parenthesis indicate the percentage of total) the research centers of cotton in different State Agricultural University were brought under one project.

1970: First commercial cotton hybrid of the world (Hybrid 4) was released from Surat by the noted breeder Dr. C. T. Patel.

1972: First commercial interspecific cotton hybrid of the world (Varalaxmi) was released from Dharwad by the noted breeder Dr. Katarki

1976: Infrastructure of cotton research got strengthened with the establishment of Central Institute for Cotton Research at Nagpur.

1982: Regional station of Central Institute for Cotton Research was established at Sirsa to strengthen the research efforts in north zone.

1999: Technology Mission on Cotton was launched.

2002: Transgenic *Bt* Cotton was approved for commercial cultivation in India.

2005: First transgenic extra long staple interspecific *Bt* cotton hybrid (MRC 6918) of M/s. Mahyco was approved for commercial cultivation in India.

2006: Transgenic extra-long staple interspecific *Bt* cotton hybrid (RCHB 708) of M/s. Rasi Seeds was approved for commercial cultivation in India.

Currently, several conventional extra-long staple *G. hirsutum* and *G. barbadense* varieties as well as hybrids (both intra hirsutum and inter-specific hybrids) having more than 32.5 mm of 2.5 per cent span length, which were released under AICRP on Cotton, are under cultivation in India (Table 3).

The major problem with regard to long and extra long staple cotton varieties and hybrids in India is that these varieties are cultivated in varied agro-climatic conditions including rainfed situations, which lead to the variation in fibre quality attributes. For instance, the fibre quality attributes of some of the varieties / hybrids which showed the variability in the lint sampled in the market are furnished in Table 4.

It is evident from the Table 4 that Indian cottons in the staple group 31- 36 mm have been found to have lower micronaire value not

Table 3. Extra Long Staple Conventional Cottons under cultivation

Variety/Hybrid	2.5 per cent SL (mm)	Mic	BS 3.2mm	Count	Year	Species
MCU 5	33.0	3.2	26.0	60s	1968	H
Varalaxmi	34.0	3.2	28.0	80s	1972	HB
Suvin	38.0	3.2	38.0	120s	1974	B
DCH 32	36.0	3.0	30.0	80s	1981	HB
MCU 5 VT	32.5	3.3	25.0	60s	1982	H
VRS 7 (Surabhi)	32.5	3.2	24.0	60s	1996	H
CDHB 1 (Sruthi)	35.0	3.5	28.0	80s	1996	HB
CO 14	35.0	4.0	23.4	70s	2016	H
Phule Prabha	34.8	3.3	26.6	80s	2016	HB
Subiksha	32.7*	3.7	33.8*	60s	2018	H

*under HVI Mode

exceeding 3.5 units in majority of the cases as compared to an average value of 4.0 in import growing. The lower micronaire value has been found to be not due to intrinsic finer nature of the cotton but has more to do with immaturity arising from lack of adequate cell wall development. The tenacity values in Indian cottons in this category have been noted to be on the lower side by about 4 – 10 g/tex.

From the above discussion, it is clear that the ELS cotton should be cultivated in ideal agro climatic condition to achieve the maximum lint yield as well as the uniform and better fibre quality. Some of the potential areas for augmenting ELS cotton in India may be Salem, Dharmapuri, Coimbatore and Erode districts in Tamil Nadu; Mysore, Chamrajnagar, Chickmagalur, Shimoga, Dharwad, Davangare, , Belgaum, Hasan, Tumkur, Bijapur and Gulbarga districts in Karnataka; Khandwa in Madhya Pradesh; and Anand and Talod in Gujarat.

Ever since three *Bt* cotton hybrids have been approved for commercial cultivation in India during 2002, there was a sharp increase in area under cultivation of such hybrids. Several ELS Bt cotton hybrids have been released by private sector and can contribute towards increased ELS production with required thrust for cultivation of ELS cotton through Best Management Practices, besides matching marketing facility and assured buy back in case of contract farming. The characteristics of some of the ELS *Bt* cotton hybrids are furnished in Table 5.

Since cotton is processed into yarn in groups of fibres rather than as individual fibres, properties such as length variability, short fibre content, fineness, maturity and bundle strength among others influence the yarn quality and strength and resulting in textile products. Steady gains in longer fibre and higher bundle strength have been accomplished through breeding in 20th century.

Improvements in fibre quality have long been a primary objective of cotton breeders. One major obstacle for early breeders was the lack of reliable methods to measure fibre characteristics. Those methods have become available with the advent of HVI in late 1960s and AFIS in 1980s. During the last two decades, cotton breeders have used HVI (High Volume Instrument) as their primary and often sole source for fibre quality evaluation and using the HVI data for making plant selections, especially in India. However, earlier research recognized the need for additional information about AFIS properties and the potential role of AFIS in breeding programmes. The intent of the AFIS design was not to correlate other fibre measurements with AFIS. It was designed to provide unique fibre data. Fibre data generated by Advanced Fibre Information System

Table 4. Fibre Attributes of cottons in the staple group 31 to 36 mm

Variety/Hybrid	2.5 per cent S.L.(mm)	U.R. (%)	Mic. Value	Tenacity (g/t)
DCH-32	30.1 – 37.9	42 – 53	2.6 – 3.9	23.4 – 29.6
G. Cot Hybrid 102	38.8	52	3.2	29.9
Surabhi	31.3 – 34.2	45 – 51	3.3 – 4.6	21. 5- 27.1
Suvin	38.8 – 39.4	46 – 50	3.5 – 3.6	32.7 – 35.4

technology is also now available to plant breeders, and provides additional information on length characteristics and fibre maturity. Variation in fibre lengths and therefore shape of the distribution curves vary across cultivars with more uniform length and distribution desirable to reduce wastage in spinning and to produce better yarn.

The quantity of short fibres in a cotton sample is an important cotton quality parameter. Short cotton fibres have detrimental impacts on yarn production performance and yarn quality. There are different parameters for characterizing the amount of short fibres in a cotton sample. The most widely used parameter is short fibre content (SFC). It is a general practice in the textile industry to remove short immature fibres in the combing process to improve the fibre length distribution and tenacity.

The AFIS instrument individualizes and presents individual fibres to electro-optical sensors in order to measure fibre maturity, which is otherwise difficult in conventional method, and requires only very little quantity of lint for testing. Further, AFIS method of maturity measurements shows good correlations with the reference method.

Cotton fibre maturity, degree of secondary cell wall thickening relative to the perimeter, is one of the most important fibre quality and processing parameters of cotton. Immature fibres result in low dye uptake, increased fibre breakage, fabric defects, and waste.

It has been clearly established that short fibre content and immature fibre content play a major role in determining the quality of fibre based on study to compare the fibre quality of the long staple cotton variety, Suraj using HVI and AFIS. By reducing the short fibre content, bundle strength can be improved to a greater level, especially in long staple cotton.

Future thrusts:

- Basic and applied aspects of research on cotton fibre quality improvement suiting to modern textile industry needs keeping in backdrop the necessity of sustained production of appropriate staple requirements.
- Development of *G. barbadense* cultivars which are better than Suvin in terms of seed cotton yield, ginning outturn and micronaire through both conventional and biotechnological approaches to cater

Table 5. Popular Extra Long Staple Bt Cotton Hybrids under cultivation and their characteristics

H X B Hybrid	Company	2.5 per cent Length (mm)	Micronaire	Tenacity (g/tex)
MRC 7918 BG-II (Bahubali)	M/s. Mahyco	35.3	3.5	31.0
MRC 6918 XXL BG-II	M/s. Mahyco	35.6	3.7	29.7
RCHB 708 BG II (EXCEL)	M/s. Rasi Seeds	35.2	3.7	25.6
NCHB 9905 (Kisan Jyothi) Bt2	M/s Nuziveedu Seeds	35-36	2.8-3.5	36-37
NCHB 9903 ELS Cot Bt2	M/s Nuziveedu Seeds	35-37	3.0-3.5	35-36
Chamundi BGII	M/s JK Agri Genetics	35.4	3.2	30.1

to the needs of increasing demand of Indian textile industries.

- Identification of superior parental combinations in case of interspecific hybrids which can result in increased seed cotton yield, lesser susceptibility to sucking pests and have lesser mote contents.
- Improving the fibre length and strength of *G. hirsutum* cultivars as well as intra-hirsutum hybrids matching the fibre qualities available in the foreign market.

3

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Yield improvement in rainfed cotton through new plant type concepts – a perspective

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Cotton commonly termed as 'white gold', dominates Indian cash crops, and makes up a lion share of 65 per cent of the raw material requirements of the Indian textile industry. The Mongol-Tartar dynasty brought cotton to China from India in the thirteenth century. Presently, China and India are the largest producers of cotton in the world. Though China having only half the area under cotton production as compared to India, could be able to produce one and-a-half times more cotton, with one-and-a-half times the global market share and three times the yield.

Over all Cotton production across different zones of India is given below

Zone	Production (in lakh bales)	States
Total North zone	56	Punjab, Haryana, Upper Rajastan and Lower Rajastan
Total central zone	207	Gujarat, Maharstra and Madhya Pradesh
Total South zone	95	Telangana, Andhra Pradesh, Karnataka and Tamilnadu
Total	362	

Indian scenario : challenges in Indian cotton sector : In India cotton is cultivated in about 12 million hectares, with around 35 million bales and average yield that ranges from 500 – 540 kg/ha vis a vis global average productivity of 700 to 800 kg/ha. Cultivation of cotton is confined to 60 per cent of rain fed areas that are characterized by shallow soils, where uncertain monsoon and deficit rainfall prevail more frequently. This is resulting in low productivity due to negative effect of low soil moisture on boll formation and retention.

Net return as percent of price had squeezed post 2010-2011, with many states hitting at negative growth during 2014-2015 and 2015-2016. Cotton production is becoming less attractive, but area is increasing since it is grown mostly in rain fed conditions where there is no alternative crop better than cotton. Farmers have realized profit margins because of increased value of output through increased productivity and better prices. The recent, steep hike of 28 and 26 per cent in the minimum support price (MSP) on medium-staple and long-staple fibre cotton respectively by the government, will surely benefit the farmers, but the same MSP operational for all states is questionable, as the cost of production varies across the cotton growing states (Anuradha Narala In. cotton statistics and news 33: 2018-2019)

In the countries like USA, Australia,

China, Brazil and Uzbekistan, suitable plant types were developed to accommodate plant densities ranging from 1.0 lakh to 2.5 lakh plants/ha using narrow and ultra narrow spacing. However, in India the recommended plant density for cotton seldom exceeds 55000 plants/ha.

Challenges for Telangana : Large area is under cotton cultivation in Telangana (17.00 lakh ha). The crop suffers from mid season or terminal drought. The productivity however remains stagnated at 550-600 kg/ha. Productivity has to be improved in these light soils which show low moisture retention capacity by developing short compact genotypes with early maturity and that suit HDPS. Advantage of HDPS is earliness with high plant population with less bolls/plant that paves way for high yield than conventional cotton. The crop does not have to maintain the late formed bolls. Plant type features include short stature, medium boll size 3.5 to 4g, few smaller and thick leaves with sparse hairs, high degree of resistance to pests and diseases. Current day scientists were trying to modify the planting geometry and existing plant type features.

Planting geometry and existing plant type features

Narrow row (NR): The planting geometry adopted is 8-10 cm distance between plants in a row at row spacing that ranges from 18 to 106 cm. The planting systems are referred to as narrow row (NR) if the row-to-row spacing is less than 75 cm

Ultra narrow row (UNR): Here the spacing is 45 cm. Ultra Narrow Row (UNR) cotton was initiated by Briggs *et. al.* (1967). It is a system that can accommodate a plant population of 2.0 to 2.5 lakh plants / ha against conventional planting system with a plant population of 50,000 plants / ha. The UNR cotton plants produce fewer bolls per plant than conventionally planted cotton but retain high percentage of total bolls in the first sympodial position than second sympodial position besides having better light reception, efficient leaf area development and early canopy exposure which reduce the competition with weeds. The early maturity of the genotypes can make this system ideal for marginal soils under rainfed conditions.

High density planting system (HDPS): HDPS is considered as an alternative production system having a potential for enhancing the productivity of rainfed cotton besides, reducing input costs efficient surveillance against pests and diseases and minimizing risks associated with present cotton production system

Plant type features needed for Irrigated conditions of north India : Singh *et* al. (1974) proposed an ideal type for tetraploid (G. *hirsulum* L) and diploid (*G. arboreum* L) cotton under irrigated conditions which include short stature (90-120 cm), compact and sympodial plant habit with unimodal distribution of bolling and high degree of inter plant competitive ability. Other features include short stature (90-120 cm), short duration (150-165 days), boll size 3.5 to 4 g, responsive to high fertilizer dose, high degree of resistance to insect pests and diseases

CSH 3075 was the first cotton variety released for HDPS in India. For deep soils under supplemental irrigation the variety Suraj could be planted at 75x10 and 90x10 cm where as 60x10 cm was optimum on shallow–medium soils under rainfed conditions

Semi-compact genotypes with favourable morphological traits include PKV 081, Suraj, NH 615, NH 630, ADB 39, LRK 516, F2383, CSH 3075, ADB 39, NDLH 1938 and KC 3 in G. hirsutum and Phule Dhanwantary and AKA 7 in *G. arboreum.*

On other hand hybrids provided increased productivity coupled with robustness of cotton led to increase in number of pickings. Even though the robust hybrid plant types have contributed to increase in boll number and seed cotton yield, the remunerative value of robust hybrid cotton plant has at times taken a beating because of increase in cost of hybrid seed, plant protection measures against sucking pests, harvesting cost associated with manual picking and lower per day productivity

Plant type for HDPS : Compact, short stature, main stem bearing, early maturing genotypes with medium to big boll is the need of the hour. Unfavourable ecologies compelled cotton farmers of such regions of India to adopt HDPS. The system is followed with *Bt* hybrids and semi-compact genotypes with a plant population of less than 1,00,000/ha. The experiments indicated that productivity of more than 1000 kg lint/ha is possible yet even in marginal shallow soils under rainfed situation. The resulting yields at 45 x 15 cm and 60 x 15 cm were *on par* and superior to 90 x 15 cm. Genotypes ADB 39 (3000 kg /ha), PKV 081 (3011 kg /ha) and LRK 516 (2814 kg/ha) performed well at 45 x 15 cm spacing whereas genotypes NH 545 (2830 kg/ha), NH 615 (2633 kg /ha), KC 3 (3113 kg / ha) and Suraj (2976 kg /ha) gave highest yield at 60 x 15 cm spacing (Venu Gopalan *et al.,* 2013). Production technology wise sowing in the 3rd week of June, bullock / tractor seed drill / planter 45 x 10 cm (90,000 plants/ac) or 60x10 on medium soils (67000 plants/ac) or 75x 10 cm on deep soils for central India, 25 per cent additional fertilizers over the recommendation for varieties, growth regulator mepiquat chloride @ 50 g ai /ha in 2 or 3 splits decreased plant height.

Average yield improvement under HDPS was around 30 per cent over the recommended spacing (60x30 cm) and the earliness was around 10 days. The objective is to limit the boll number to 6-8 bolls/plant, maximise the bolls/unit area and realise high yield in the shortest possible time. If the bolls/ plant is few, the fruiting window (or flowering period) is short (4-5 weeks) and the plant matures early, producing fibres with good quality. HDPS elicited great interest across the country. Farmers were convinced about the feasibility of the technology especially under rainfed shallow soil situation. Efforts are also underway to breed ideally short (90-100 cm) compact, zero monopodial plant types with early maturity, having tolerance to sucking pests, with 6-7 bolls/plant under high planting density with big boll size that would ideally fit into the system. *Bt* genes have been introduced into the semi compact varieties already identified suitable for HDPS and this would dispense the fear of American bollworm.

Advantages of HDPS:

- Early crop maturity and higher production on areas with short growing season
- Suitability for rainfed cotton production on shallow and medium deep soils where cotton crop invariably experiences terminal drought
- High seed cost with the use of present day *Bt* hybrids
- Lack of availability of *Bt* varieties to suit HDPS right now.

Limitation of HDPS:

- Cotton breeders consciously bred bushy, monopodial varieties resembling hybrids with the aim of maximizing the number of bolls / plant. Breeding for early maturing, dwarf, compact BT varieties with fruiting bodies close to the main stem that would suit HDPS, has not gained momentum coupled with picking machine
- Cotton is often grown in water-deficit regions. Cotton is a perennial, broad-leafed, drought tolerant plant with a taproot. Grain crops are in the grass family and have horizontal roots, good for stabilising soil but leaving crops vulnerable to water stress.
- Cotton is a woody perennial with vertical roots that typically descend 1.5 meters, allowing it to provide an economic yield in semi-arid and arid regions where food crops would fail. This is why cotton is grown in the middle of Maharashtra

Status of mechanical picking of cotton in India and abroad : Mechanical picking warranted short, compact (short sympodes) and determinate genotypes. To retain their architecture and maximise productivity from these plant types, close planting was a necessity. By use of compact plant varieties outside countries have been able to accommodate plant densities varying from 1.0 lakh to 2.5 lakh plants /ha. On the contrary, Indian farmers are using robust hybrids due to which the plant population seldom exceeds 50,000 plants /ha which may be one of the reasons for low productivity *i.e.*, around 500 kg /haeven after the introduction of *Bt* cotton hybrids.

- In India, normally farmers go for two to four pickings of cotton till complete harvesting.
- It is expected that 85-90 per cent of the seed cotton (*kapas*) is picked during the initial three pickings and the subsequent pickings sometimes may not be economical even by manual labour.
- Cotton picking is tedious, highly labour dependant and much costlier than all other cotton operations.
- The cost of picking alone accounts for 25 per cent of the total cost of cultivation. During the peak season, the availability of labour for cotton picking becomes even more scarce.
- Cotton is completely machine-picked in Australia, Israel and U.S.A. Over 90 per cent is machine picked in Greece, Mexico and Spain. Almost 75 per cent of total production is machine- picked in Brazil. In most of other countries including China, India and Pakistan, cotton picking is done manually

Problems with mechanical harvesting

- Lack of suitable genotypes at present for single picking

- Mechanization means the picking can be done only once. Thus, the opening of the cotton bolls may have to be synchronized
- Synchronous boll opening
- The plant height of cotton varieties/ hybrids cultivated in India is up to six feet or even more, which does not match mechanical picking specification. Thus, managing the cotton plants' height is another major issue.
- High cost of machinery
- No basic categories of chemicals such as, defoliants, desiccants, boll openers / conditioners / enhancers and re-growth inhibitors, etc. used as harvest aids are presently available in India.
- Spraying of growth regulators and defoliants increasing cost
- Almost all varieties/ hybrids (including *Bt* hybrids being largely cultivated in India) are sympodial which are not suitable for mechanical harvesting of cotton.
- Results in more trash content
- Hand-picking of cotton results in 2-2.5 per cent trash content. Trash is much higher in cotton picked mechanically. For ginning mills, pre-cleaning will become a big operation.

Today's need - cotton with least contamination : 16 types of contaminants identified in Indian cottons.

- Indian cottons being processed are either moderately or seriously contaminated by 'organic matter', *i.e.* leaves, feathers, paper, leather, etc. or by other serious contaminants such as 'fabrics' made of cotton, 'strings' made of woven plastic and plastic film and 'inorganic matter' in the form of sand or dust. Also of concern are in descending order of incidence, woven plastic and plastic film fabrics, cotton strings, jute/hessian fabrics and grease or oil. "Fibre cultivation to yarn spinning stage" remains a major source of contamination
- The quality of Indian cotton also gets deteriorated because of varietal admixture. . Indian farmers have the privilege to cultivate any variety/ hybrid and right to get all varieties/ hybrids to mix them before bringing the same to markets

What needs to be done? To adopt mechanical picking of cotton in India, lots of changes in agronomic practices

- Adoption of mechanical harvesting by Indian farmers is not dependent just upon the availability of suitable harvesters, but also depends on availability of appropriate cotton varieties; suitable agronomic practices like the seed rate, nutrient and defoliant application; systems for pre-cleaning of cotton before sending it to cotton gins / Ginning and Pressing units.
- Plants needs to be uniform and much lower in height for mechanical picking
- Evaluation of chemicals is to be done that may be required to control plant height and to keep it uniform

Plant aspects to be taken care

(Agronomic practices)

- Profitable row ratios (inter and intra) have to be worked out for accommodating more population.
- Specific chemicals are needed for growth regulation and defoliation
- Suitable crop management practices in HDPS need to be worked out
- Apart from hybrid seeds and *Bt*-technology, we also need to look at mechanization coupled with high density planting, to further increase the productivity, breeding of mainstem or sympodial bearing types than the present day dual types, synchronous maturity, compact plant with less foliage and earliness.

Limitations : Indian farmers are habituated to grow cotton hybrids/varieties that are space planted and give yields in 3-4 pickings with good response to input application. On the contrary HDPS cotton necessitates high plant population with very narrow spacing and one time picking. Genotypes with uniform maturity short duration, reasonably big boll type are required to bred for mechanical picking completely with minimal crop management sprays.

Breeding approaches : Multiple crossing to identify cotton genotypes with short and compact architecture possessing short sympodia and lowest or zero monopodia that enable the genotypes to adjust to various agronomic manipulations. Focus to be on development of varieties amenable for HDPS through studies on combining ability, heterosis and stability for productive traits and plant type along with better quality of the fibre. Interplant crosses (robust x compact) were developed through line x tester mating design and intraplant (robust x robust) crosses were developed through 7x7 diallel mating design. Comparison of interplant type crosses with intrarobust crosses revealed that, interplant type crosses showed reduction in plant stature and were found more productive and heterotic for seed cotton yield than intrarobust crosses. Cross combination MC 17-6 x MC 3-2 had shown stable performance over different locations for the traits seed cotton yield, length of the sympodia, leaf area, number of bolls, 2.5 per cent span length and bundle strength (Murthy et al. 2017). Hybrids with short plant stature (30-35 cm), more number of short sympodial branches (6-8), less or zero monopodia, medium to high bolls/plant (8-12), high leaf area, high harvest index (50% and above) with desirable fiber quality may be useful in promotion of compact hybrids under HDPS (Murthy *et al.* 2017).

For high density planting (HDP) at least one of the parents must be of open plant type with determinant plant growth habit, whereas second parent can be of compact plant type and growth pattern, provided there is nice complementation with the first parent

Future line of work : The productivity of rainfed cotton in marginal shallow soils can be enhanced by developing plant types suitable for HDPS. The suitability of the genotypes to HDPS was not critically evaluated except in a few cases. However, a few genotypes like Suraj, PKV 081, NH-615, KC3, Anjali, F2383 and ADB-39 were identified and evaluated at higher plant densities of 1.5 to 2.2 lakh plants/ha at 45-60 cm row spacing. There is a need to develop ideotypes like ADB-39 and 532 with *Bt* background for faster adoption of the technology.

Exploiting heterosis and combining ability by making hybridization between robust and compact plant types, compact and compact plant types and compact and semi compact plant types. Multiple crossing programme with 1-2 cycles of inter mating in segregating populations would likely to through desirable recombinants by breaking the tight linkages. Genotypes/ hybrid combinations identified in different studies could be evaluated under HDPS along with studies on root, biochemical and physiological traits related to drought tolerance to identify plant types suitable for light soils under rainfed conditions at increased plant densities in addition to genetic analysis of the cotton genotypes by using EST-SSR markers. Priority to be given to study the variability for inherent seed dormancy among the genotypes, which could be used for identification of varieties that can avoid germination of seeds due to rains coinciding with maturity stage.

To improve the productivity levels, development of compact and semi compact plant types with less number of monopodia, more number of short sympodia, medium boll weight (3-4 gr), 8-14 bolls/plant, earliness and synchronous maturity along with good physiological attributes need to be prioritized

Disruptive technologies needed to break the yield barriers

- To reach this level of increase in yields, we need to strategically introduce next generation traits like *Bt*3, *Bt*4, herbicide tolerance, water and nitrogen use efficiency, high density planting pattern, mechanical harvesting system, etc.
- Replacement of the bullocks with tractors, organic to inorganic fertilizers, hybridization, GM crops, no-till, fancy and sophisticated farm equipment like self-propelled sprayers and combines equipped with advanced telematics may take more than 40 years for full adoption
- As of now, the mechanical cotton pickers suitable for Indian field test conditions operate by suction valve and include Pneumatic Cotton Picker; Power Tiller Operated Cotton Picker and Tractor Operated Cotton Picker. Recently, John Deere has come up with two-row pickers in Turkey and Uzbekistan, but the company has yet to figure out what type of mechanical picker would be suitable for Indian conditions

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Poly ethylene mulching – A boon or bane for cotton cultivation

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Mulching has been practiced in India since long time using mainly the crop residues like straw,trash,stalk,leaves etc.,but of late plastic mulches have come into use due to its inherent advantages of efficient moisture conservation, weed suppression and maintenance of soil temperature for faster mineralization. The advantages of using plastic mulches for the production of high value vegetable crops have been recognized since 1950's in United states and European countries and its use for moisture conservation, weed control and enhancing crop productivity has been explored for cotton based cropping system and the results were highly encouraging and it has potential to be explored fully so that the recent concept of more crop per drop of water could be achieved.

Advantages of poly mulching

- Poly mulching prevents direct evaporation of moisture from the soil and thus limits the water loss and conserve moisture.
- The moisture that evaporates under poly mulching is condensed below the mulched layer and reused by the crop.
- The suppression of evaporation also has a supplementary effect as it prevents the rise of water containing salt, which is important in places where salty water is mainly used for irrigation.
- Since minimum quantity of water is needed for poly mulched crop , 40-50 per cent saving of irrigation water as compared to conventional method and if poly ethylene mulching is combined with drip irrigation , the water saving could be as high as 85 -90 per cent.
- Reduced water requirement under poly mulching indirectly helps in reduction in EC in the soil as minimum quantity of salty water is being added to the soil.
- The loss of nutrients through leaching is kept under minimum.
- Opaque mulches prevent weed growth and save weeding cost and also help us in preventing the use of toxic herbicides into the soil ecosystem.
- The soil under poly mulching is friable and well aerated which is ideal for plant growth.
- The soil erosion is completely arrested under poly mulching.
- During heavy downpour, the rain water could not stagnate under poly mulching
- Root pruning is completely eliminated as no inter cultivation is needed for poly mulched cotton.
- The poly mulched plants were sturdy and could not collapse due to pests like stem weevil due to strong vascular bundles.
- The leaves are thicker and leathery and

recorded lesser incidence of sucking pests.

- Reflective silver colored mulches helps in reduction of pests as the small insects could not land on the shiny poly mulched area. The viral diseases also could be checked under poly mulching due to lesser occurrence of insect vectors
- Higher CO_2 assimilation and enhanced crop production efficiency.
- Cleaner produce and no soil is splashed to the produce

Use of polyethylene for Cotton based cropping system has been successfully done at CICR Regional Station,Coimbatore. The results are highly encouraging .

Table 1. Response of cotton variety LRA 5166 for poly ethylene mulching

Characters	Poly mulched	No mulch control
At 90 DAS		
Root CEC m.e/100g roots	**24.9**	15.3
Root length (cm)	**27.4**	21.8
Root weight (g/plant)	**4.3**	1.6
Secondary roots	**23.5**	13.1
Root volume (cc)	**13.3**	5.2
Leaf numbers/plant	64.6	41.4
Leaf area/leaf	**63.3**	20.6
Leaf dry weight (g/leaf)	**0.61**	0.22
DMP(g/plant)	**40.0**	15.5
At harvest		
Sympodia / plant	18.2	15.9
Bolls/plant	32.0	18.6
Boll wt (g/boll	4.01	3.54
Seed Cotton Yield (kg/ha)	2559	1368
WUE (kg of seed cotton/ ha cm)	43.2	16.5

Evaluation of different thickness poly ethylene as mulching : Various thickness poly film of 30, 50, 75 and 100 micron were evaluated and all the thickness were found suitable and were on par. Since the cost of mulch film is based on weight, the lower thickness of 30 - 40 micron is recommended to reduce the cost. While using thinner poly film of 30 micron, care should be taken to handle the film smoothly so that the film will be used for two crops at once over laying.

Coloured polyethylene as mulching : Differently coloured poly ethylene mulching of black , red, blue, yellow and silver colour were evaluated and it was found that irrespective of the colours, the poly ethylene mulching promoted the growth and development of cotton significantly over conventionally planted cotton. The silver colour recorded the lowest pest incidence due to reflective action. While, the yellow colour attracted the sucking pests in cotton and the yield enhancement was highest with silver colour poly film. The enhancement in seed cotton yield due to coloured poly mulching was to the tune of 1.96, 1.75, 1.71, 1.68 and 1.57 fold respectively in silver, blue, red, black and yellow colours over conventional method. We recommended dual colur poly film of silver colur top layer with black bottom layer for reflective action by silver colour and for faster mineralization by black bottom layer.

Influence of poly mulching, drip and poly mulch + drip on growth attributes of ELS cotton : The poly ethylene mulching promoted the growth of cotton ELS cotton cv RCHB 708 Bt

Table 2. Soil temperature, Available Soil Moisture, Nutrient uptakes, rhizosphere and phyllosphere micro organisms in cotton ,LRA 5166 due to poly mulching

Characters	Poly mulched	No mulch control
Soil temperature across soil depth up to 45 cm (^{o} celsius)	29.2	27.6
Available soil moisture (%)average at 20 DAS interval	23.20	18.26
Nutrient uptake (g/plant) on 90 DAS		
Nitrogen	1.98	0.93
Phosphorus	0.25	0.09
Potassium	2.50	0.97
A. Rhizosphere soil of cotton (/ gram of dry soil)		
Diazotrophs	164.2 x 10^4	63.7 x 10^4
Facultative Methylotrophs	109.2 x 10^4	26.4 x 10^4
Azospirillum	19.2 x 10^4	6.7 x 10^4
Phosphorus solubilizing bacterias	90.57 x 10^3	42.9 x 10^3
B. Phyllosphere of cotton /g of fresh leaf		
Pink Pigmented Facultative Methylotrophs	134.6 x 10^4	39.3 x 10^4
C. Root bits (rotation maize)		
Arbuscular mycorrhizae infection(%)	90.0	73.3

significantly as evidenced from taller plants of 135 cm to 146 cm under poly mulch + drip system as compared to 120.3 to 123.7 cm under drip system without poly mulch and 105.3 cm under conventional system. The leaf production rate was much faster under poly ethylene mulching with or without drip as could be seen from 264 to 304 leaves /plant at 90 DAS as compared to 222 to 295 leaves under drip without poly ethylene mulching. The poly mulching under conventional irrigation produced 60 leaves more than conventional method .This might be due to favorable microclimate under polyethylene mulching with higher available soil moisture, enhanced soil temperature, lesser weeds competition etc., The leaf area also significantly higher in poly ethylene mulched cotton with or without drip and superior to drip system without poly ethylene mulching and conventional method.

The healthy plants under poly mulching and poly mulch + drip system resulted in production of more branches as evidenced from 32 to 33 nodes/plant than either drip alone or conventional method. The poly mulch + drip at 0.8 Etc recorded the highest (33.3) nodes /plant and the lowest (27.6) under conventional method. The poly ethylene mulched cotton recorded enhanced dry matter accumulation of 1.97 fold than conventional method. Drip at 0.4 Etc without poly mulching also recorded significant reduction in dry matter accumulation.

Yield attributes : The favorable microclimate under poly ethylene mulching with

Table 3. Growth attributes of ELS Cotton, RCH B 708 Bt cotton on 90 DAS as influenced by Drip, Poly mulching and Drip + Poly mulching

Treatments	Plant height (cm)	Leaf numbers/ plant	Leaf area (cm^2/leaf)	Node/ plant	DMP g/ plant
T1- control	105.3	243.3	183.9	27.6	186.5
T2- Poly mulching	135.0	303.3	264..8	31.0	314.5
T3 – 0.4 Etc (Drip)	120.3	222.3	224.9	28.6	199.2
T4 - 0.4 Etc (Drip + PM)	146.0	264.0	232.0	32.0	341.9
T5- 0.8 Etc (Drip)	123.7	295.0	246.2	29.3	362.8
T6 – 0.8 Etc (Drip + PM)	141.0	304.0	264.5	33.3	366.9
CD (P=0.05)	13.23	55.79	33.03	1.76	84.5

Table 4. Yield attributes, Seed Cotton Yield and water use efficiency of ELS Cotton RCHB 708 *Bt* as influenced by Drip, Poly mulching and Drip + Poly mulching.

Treatments	Sympodia/ plant	Bolls/ plant	Boll weight (g/boll)	Seed Cotton Yield (kg/ha)	WR*	WUE
T1 - Control	22.3	42.5	4.9	3450	92.7	36.0
T2 - Poly mulching	23.6	77.4	5.3	4982	70.6	89.0
T3 - 0.4 ETc (Drip)	21.4	67.4	5.4	4009	57.3	90.0
T4 - 0.4 ETc (Drip + PM	24.1	82.5	5.6	5494	57.3	123.5
T5 - 0.8 ETc (Drip)	22.4	73.4	5.2	4551	67.5	85.4
T6 – 0.8 ETc (Drip) + PM	25.1	82.5	5.4	5486	67.5	102.9
CD (P=0.05)	1.71	5.48	NS	497		

WR*includes 30. 8cm of effective rainfall

or without drip on growth components were finally reflected in better assimilate partitioning to reproductive structures as evidenced from the production of 82 - 94 per cent higher number of productive bolls than conventional method. Poly mulch + drip either at 0.4 or at 0.8 ETc produced significantly higher number of harvestable bolls/ plant.

The polyethylene mulching alone or in combination with drip system recorded heavier bolls ranging from 5.3 to 5.6 g/boll as against 4.9 g/boll under conventional method. However the boll weight was not significantly altered by the treatments.

Seed cotton yield : The favorable growth condition under poly ethylene mulching and poly mulch + drip system has resulted in significant enhancement in assimilate partitioning towards economic produce with many fold enhancement in production of harvestable bolls in cotton cv RCHB 708 Bt contributing significantly to higher seed cotton yield ranging from 44.4 to 59.3 per cent higher yield than conventional method. The yield enhancement due to drip system ranged from 16.2 – 29 % higher than conventional method. The poly ethylene mulch + drip at 0.4 Etc recorded 20.7 per cent higher seed cotton yield than drip at 0.8 Etc without poly ethylene mulching. Among the treatments, poly mulch + drip at 0.4 ETc was on par with poly mulch + drip at 0.8 Etc and found significantly superior to rest of the treatments.

Water requirement and water use efficiency : The total water requirement ranged from 57.3 to 92.7 ha cm. The water requirement at 0.4 Etc was 57.3 cm and at 0.8 Etc was 67.5 ha cm as against the conventional method of 92.7 ha cm. Poly mulched cotton with or without drip recorded higher water use efficiency than drip alone without poly mulching. Among the treatments, drip at 0.4 Etc + polyethylene mulching recorded the highest water use efficiency of 123.5 kg seed cotton /ha cm for RCHB 708 Bt cotton as against 85.4 kg seed cotton/ha cm at drip at 0.8 Etc without poly ethylene mulching, The lowest WUE of 36 kg/ ha cm has been recorded under conventional method**.**

· Drip + poly mulching recorded 46.1 % and 86.5 % higher seed cotton yield than drip irrigation without poly mulch and conventional method respectively.

Table 5. Seed Cotton Yield in ELS cotton, RCHB 708 Bt as influenced by Water Conservation techniques and fertilization practices

Fertilization Treatments	Water conservation Techniques			MEAN
	Drip	Drip + Poly Mulch	Control	
T1 - 100 % NPK	3740	5920	3290	4316
T2 - T1 + Zn SO4	4460	6480	3720	4886
T3 - T1 + Mg SO4	5320	6970	3820	5370
T4 – T1+ Boron	5200	7370	3910	5493
T5 – **T1 + Zn SO4+ Mg SO4 + Boron**	5760	**7820**	4110	5896
T6 -75 % of T5	4430	7660	3920	5336
MEAN	**4820**	**7040**	**3775**	
CD (P=0.05) for W	416			
CD (P=0.05) for F	599.0			

· Balanced fertilization with 120: 60:60 kgs NPK /ha along with zinc sulphate (50 kg/ha), magnesium sulphate (50 kg/ha) + Boron as Solubor (1 kg /ha for soil application and 0.15 per cent as foliar spraying twice during flowering to boll development stages recorded the highest (**7820 kg/ha**) seed cotton yield as against 3290 kg/ha recorded under conventional irrigation with NPK alone

Zero tilled rotation maize – a new concept under poly ethylene mulching

A new concept of growing the rotation crop of maize under polyethylene was attempted and the second crop of maize also benefited due to the favourable growth environment created under poly ethylene mulching.

Table 6. Growth and yield attributes of maize hybrid, CORH M4 as influenced by Poly ethylene mulching

Treatments	Plant height (cm)	Leaves/ plant	DMP (g/ plant)	Cob length (cm)	Cob diameter (cm)	Grain rows/ cob	Grains/ row	100 seed weight (g)	Grain yield (kg/ha
T1 - 100 micron	257	13	195	32	16.33	29.67	15.67	25.50	6507
T2 - 75 micron	297	14.33	217	32	15.33	37.67	14.67	23.43	6722
T3 - 50 micron	280	13.67	210	29.67	16.00	36.33	15.67	25.30	6990
T4 - 30 micron	**270**	13.67	197	29.67	17.67	36.67	15.33	26.73	6932
Mean for mulch	**225.4**	**13.67**	**204.8**	**30.83**	**16.33**	**35.09**	**15.34**	**25.24**	**6788**
T5 - Control	228	11.00	137	22	10.67	29.67	13.33	19.23	3322
CD (p=0.05)	17.22	1.38	47.28	3.13	2.17	4.71	1.31	4.07	870.0

Growth, Yield attributes and grain yield of Zero tilled rotation maize after cotton due to poly mulching : All the growth and yield attributes like plant height, leaf numbers, dry matter accumulation, cob length, cob diameter, number of grain rows/cob, number of grains/ grain row, 100 seed weight and maize grain yield were significantly enhanced under poly mulching .The enhancement in grain yield was to the tune of 1.95 to 2.10 fold than its conventionally grown maize crop.

CONCLUSION

To sum up, poly mulching is a potential and hitherto untapped option for the agricultural crops for conserving the most precious water and efficiently controlling the weeds without any herbicides and enhancing the crop production efficiency by many fold in both C_3 (cotton) and C_4 (maize) crop. However, higher initial cost of poly film is the only hindrance in advocating this technology to the small and marginal farmers of our country. While appropriate government policy like availability of subsidized poly film as in the case of drip system will go a long way in future for improving the productivity and profit of farmers besides saving the precious water and creating lesser pressure on ground water resource and thus poly ethylene mulching is definitely a boon to cotton farmers.

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Cotton leaf curl virus disease-Lessons learnt and the way forward

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Cotton leaf curl virus disease was first noticed in Nigeria on *Gossypium peruvianum* and *G. vitifolia* (Farquharson, 1912). The leaf curl was observed in our neighbouring country Pakistan in 1967 from which it has been assumed to have spread to India on *G. hirsutum* near Sriganganagar in Rajasthan through the vector white fly. Cotton leaf curl virus disease (CLCuD), after its first report on *G. barbadense* at Indian Agricultural Research Institute, New Delhi in 1989 and subsequently its appearance in patches around Sriganganagar district of Rajasthan on *G. hirsutum* in 1993, is presently restricted to north cotton zone of India. Cotton leaf curl virus disease (CLCuD) is caused by a complex of whitefly (*Bemisia tabaci*) transmitted Begomoviruses having monopartite genome with circular ssDNA associated with satellite (beta and alpha satellite) . DNA molecules Begomoviruses are emergent pathogen widely distributed in tropical, subtropical and temperate regions worldwide and are a serious threat to diverse economically important crops (Castillo *et al.,* 2011; Varma *et al.,* 2011). The genus *begomovirus* is the largest among seven genera viz. *Becurtovirus, Begomovirus, Curtovirus, Eragrovirus, Mastrevirus, Topocuvirus* and *Turncurtovirus* classified in family *Geminiviridae* (Brown *et al.,* 2015; Varsani *et al.,* 2014).

Begomoviruses originating from the New World (NW) typically have genomes consisting of two components, known as DNA A and DNA B, both of which are required for virus infectivity (Stanley, 1983). However, in the Old World (OW), although there are a small number of bipartite begomoviruses, the majority have genomes consisting of only a single genomic component, which is a homologue of the DNA A of the bipartite viruses. Briddon *et. al.,*(2001) for the first time demonstrated that the infectious clones of the monopartite begomovirus cotton leaf curl virus (CLCuV) associated with diseased cotton, are unable to induce typical symptoms in host plants. They identified and isolated a single-stranded DNA molecule approximately 1350 nucleotides in length which, when co inoculated with the begomovirus to cotton, induced symptoms typical of CLCuD, including vein swelling, vein darkening, leaf curling and enations. This molecule (termed DNA beta) required the begomovirus for replication and encapsidation. The third component of begomovirus–betasatellite complexes were the alpha satellites. Alpha satellites were not true satellites, as they were capable of autonomous replication, and were described as satellite-like. These molecules are approximately half the size (~1400 nt) of the genomes of their helper begomoviruses, although they are somewhat larger than beta satellites (Briddon *et al.,* 2004).The CLCuV/DNA beta/alpha satellite complex, represent members of an entirely new type of infectious, disease-causing agents.

Lessons learnt : In India from among 5000 *G. hirsutum* lines during 2013-2014 and 2128 lines during 2014-2015 screened against CLCuD, none of the line was found to be resistant/ immune. However, lines identified as tolerant to disease were used in pyramiding resistance against this disease (Anonymous, 2013-2014b, 2014-2015b). Subsequent to appearance of CLCuD in India, resistant variety identification and development programs were taken up which led to the development of resistant/ tolerant varieties like RS-875, RS-810, RS-2013, F1861, LH-2076, H1117, H-1226 and Hybrids like LHH144, CSHH198, CSHH238 and CSHH 243 over the years by the SAUs and ICAR institutions working in the region (Ajmera *et al.,* 2004, Radhakrishnan *et al.,* 2004, Annonymous, 2005, 2006, Tuteja *et al.,* 2005, Tuteja *et al.,* 2006, Tuteja *et al.,* 2009).

However the newly developed varieties become less resistant and ultimately susceptible to the disease in a few years period (Bhatoa *et al.*, 2009; Anonymous, 2014-15a, 2015-16). Lack of resistance in cotton against cotton leaf curl begomovirus disease complex is also demonstrated in other studies (Godara *et al.*, 2015). This may be due to appearance of recombinants in nature leading to breakdown of resistance.(Rajagopalan *et al.*, 2012,). Sibnarayan Datta *et. al.*, (2017) recently reported the detection of a recombinant, phylogenetically distinct clade of Cotton leaf curl Multan virus (CLCuMuV), suggesting rebound of CLCuMuV in this region. They could not detect Cotton leaf curl Kokhran virus-Burewala strain (CLCuKoV-Bu), which was prevalent in this region, until now. More recent studies of Quadir *et.al.,*(2019) revealed a mixed infection and different natural combinations of CLCuMuV and its associated satellites CLCuMB and GLCuA in cotton plants from India. Keeping above in view, *G. hirsutum* BG II hybrids presently grown in almost 90.0% area in India are also rigorously screened at different locations on a continuous basis using susceptible infector varieties to identify resistant/tolerant cultures for their release and recommendation to farmers under All India Coordinated Research Program on cotton by Indian Council of Agricultural Research.

Alternate approaches, such as RNAi, may reduce disease and prevent yield losses incurred due to CLCuD. Several studies investigating the application of RNAi for developing begomovirus resistance have met with different level of success (Akhtar *et al.,* 2017; Bonfim *et al.,* 2007; Hashmi *et al.,* 2011; Khatoon *et al.,* 2016; Sharma *et al.,* 2015). The key feature of RNAi includes the production of two major classes of small RNAs (siRNA and miRNA) which are involved in RNAi based mechanism. While siRNA are generated by the action of Dicer on large dsRNA of diverse origins, miRNAs are transcribed from their own genes or from non-coding RNA transcripts that fold into imperfect hairpin loop structure. Primary miRNA is processed by Dicer into the precursor miRNA, followed by the production of miRNA-miRNA* duplexes in the nucleus, and then transport to the cytoplasm for loading on the RISC (RNA-induced Silencing Complex). The miRNA-RISC consequently mediates sequence complementarity dependent gene silencing at the transcriptional/post transcriptional level, and guides RISC to partly or fully degrade complementary mRNA leading to inhibition of gene expression. No cultivar with such technology with respect to CLCuD has been demonstrated commercially.

However, Akmal *et al.*, (2017) recently selected two computationally predicted cotton-encoded miRNAs (miR398 and miR2950) that showed potential to bind multiple Open Reading Frames (ORFs; C1, C4, V1, and non- coding intergenic region) of CLCuMuV, and (âC1) of CLCuMB. Functional validation of miR398 and miR2950 was done by overexpression approach in *G. hirsutum* var. HS6. Expression of pre miRNAs was shown up to 5.8-fold higher in the transgenic (T0) lines as revealed by Real Time PCR. The virus resistance was monitored following inoculation of the transgenic cotton lines with viruliferous whitefly *(Bemisia tabaci)* insect vector. After inoculation, four of the transgenic lines remained apparently symptom free. While a very low titre of viral DNA could be detected by Rolling circle amplification, betasatellite responsible for symptom induction could not be detected in any of the healthy looking transgenic lines. In this study for the first time, efficacy of the host (*G. arboreum*)-encoded miRNAs against CLCuD symptoms was experimentally demonstrated through overexpression of miR398 and miR2950 in *G. hirsutum* var. HS6 plants. Computational prediction of miRNAs targeting virus genome and their subsequent implication in translational inhibition or cleavage based suppression of viral mRNA via overexpression could help in generating virus resistant plants.

Considerable information on disease diagnostic tools epidemiological factors was generated. (Bink, 1975, Gusain *et al.,* 1991, Iqbal, 1993, Hameed *et al.*,1994, Muhammad *et al.*, 1998, Khan *et al.* 1998, Briddon *et al.*, 1998, Briddon and Markham, 2000, Akhtar *et al.*, 2002, Chakrabarty *et al.,* 2005, Monga *et al.,* 2007, Farooq *et al.*, 2011, Monga *et al.* 2011.)

The disease has caused extensive losses in India and Pakistan which shows its economic significance and have been documented in various studies in both the countries (Sharma and Rishi, 2007, Farooq *et al.,* 2011, Monga, 2016, Maharshi *et al.,* 2017). In recent studies conducted in Hisar and Faridkot during 2012-2017, The pooled range of reduction in the bolls/ plant in corresponding to the disease rating scales 1, 2, 3, 4, 5 and 6 ranged from 1.5 to 32.2, 5.1 to 41.8, 10.6 to 60.2, 25.7 to 65.1, 33.6 to 76.0, and 33.3 to 97.2 per cent, respectively in case of hybrids RCH 134 *Bt* and BG II, Ankur Jai Bt and NCS 855 BG II whereas in general the boll number reduction due to CLCuD ranged from 4.2 to 70.0 per cent. The pooled (%) reduction in seed cotton yield/plant corresponding to disease rating scales 1, 2, 3, 4, 5 and 6 was recorded in the ranged from 3.4 to 30.1, 5.1 to 46.1, 10.6 to 57.2, 27.3 to 69.3, 37.3 to 83.3 and 23.2 to 97.4 per cent, respectively. whereas in general the boll number reduction due to CLCuD ranged from 10.4 to 73.3 per cent. (Personal communication).

Integrated management strategies like advocating tolerant hybrids, completion of sowings by15th May, eradication of weeds carrying cotton leaf curl virus (CLCuV) inoculum and whitefly management for CLCuD were developed and implemented (Monga *et al.*, 2017).

The way forward : The recent studies have revealed that the Multan virus strain (CLCuMuV) is predominant in north India at present. CLCuMuV has been evolving continuously and the evolution of recombinant begomovirus isolates might be derived via exchange of genetic material from related begomoviruses viz., CLCuMuV, CLCuKoV and CLCuRaV. This genetic diversification of CLCuMuV may lead to diverse host range (enhancing threat to other crops), transmission ability and capability of breaking resistance, hence posing a big challenge for disease management. Further studies are needed to understand the role of satellites of CLCuV vis - a-vis their mobility and detection in other crops affected by begomoviruses. A repository of existing CLCuV strains need to be developed at one center in north India which will serve as base line for future studies. The existing strains and the subsequent newly emerging strains alone and in combination should be tested for their virulence through viruliferous whiteflies inoculation and standardized agro inoculation techniques to understand the role of different stains in disease development.

Recently, two *G. hirsutum* varieties GVS 8 and GVS 9 resistant against CLCuD were procured from U.S.A and have been screened against the disease in poly house and screening nursery. Based on past three years rigorous screening, the varieties have shown consistently resistant reaction against the disease. These varieties have been used in crossing program with elite varieties of north zone for introgression of CLCuD resistance. A national program for developing varieties resistant to Cotton Leaf Curl Virus (CLCuV) with inclusion of centres of State Agricultural Universities from central and south zone also to develop populations by pooling of genes for resistance from different sources, including *G. arboreum* cotton through inter mating and pyramiding them is envisaged. Populations using resistant source *G. armourianum* have been developed at PAU Faridkot center to develop resistant varieties. The populations can then be screened at CLCuD hot spots in north India. Concerted and coordinated efforts are needed to tackle the problem of cotton leaf curl virus disease on a war footing.

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Challenges in commercialization of natural dye technology on cotton

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Presently, the interest on natural dyes is growing worldwide irrespective of the existence of these dyes in the past. The necessity to protect the environment from hazardous pollutants, depletion of the natural sources, ecological imbalance, distorted environment resulting from pollutants caused by the overdosage of toxic substances in use of synthetic dyes in dyeing textiles, associated human health problems etc., is enabling to launch a more sustainable and safer alternatives. Therefore,the resurgence of natural dyes is due to environmental consciousness among all segments of consumers globally, gaining carbon footprint points, the improvement in living standards and increase in per capita disposable income of middle class especially in Asia pacific.

It is anticipated that the global market for natural dyes may generate revenues of approximately $5 billion by 2024, growing at a Compound Annual Growth Rate of 11 per cent during 2018-2024. Among the natural dyes, the plant based dyes have dominated two thirds of the market in 2018 than the animal and mineral based dyes growing at CAGR of 12 per cent. The increasing focus on quality and performance coupled with stringent Government environmental regulations regarding pollution is expected to increase the use of natural dyes in all end-use products such as textiles & leather, cosmetics, food and beverages, pharmaceuticals and others.

The global natural dye market is driven by the innovations in treatment plants and systems. The demand for natural dyed cottons and other cellulosic fibres is increasing and it is expected to grow very fast in near future. The research and development in dyeing industry is now focusing on natural dyes in order to achieve efficient and greener future products and new processes. The main research and innovation in natural dyes is found in the use of enzymes, ultrasonic dyeing and other improved techniques that aim at avoiding the use of harmful metal mordants, utilize less water, obtain good fast shades that are comparable or better than synthetic dye shades.

Among natural dyes, indigo stands special as it is used in colouring jeans globally. Blue cotton jeans are highly preferred by youth. High demand for this colour propels the usage of unutilized lands globally for production of indigo. It is also highly priced natural dye, the export of which contributes to foreign exchange.

Many natural dye sources are identified to colour textiles, but few dyes are found to possess good potential for obtaining fast shades. Indigo is the main source for producing blue shades on textiles. Red dye sources include sappan wood, madder, safflower, morindaetc. and cochineal and lac from animal sources. The yellow and orange dye componnts are rich in marigold, annatto, cosmos flowers, turmeric, pomegranate, myrobalan, onion skin, weld, barberry, Butea flower, etc. Brown and black dyes are obtained from catechu, oak galls, walnuts, logwood, barks of arjun, eucalyptus and many trees, roots of iris plant, etc. Genuine green dyes are rare in natural dye domain. Very few sources include eclipta, gulmohar, henna, jack tree bark etc. Very fast grey shades are obtained from Ratanjoth (Alkannatinctoria).

Today natural dyes have a variety of applications. They are used not only in textile dyeing and functional finishing (antimicrobial, antifeedant, deodourising or UV protective), but also as food and cosmetic colourants, cosmetic healing additives, handicrafts, pH indicators, Eco-colour powders for human use, paints and in several other applications. Natural dyes are identified and numbered in Colour Index. The number of natural dyes listed in Colour Index (as per vol 3 of CI) are

1. Natural Reds – 32
2. Natural Oranges – 6
3. Natural Blues – 3
4. Natural Greens – 5
5. Natural yellows – 29
6. Natural Browns – 12
7. Natural Blacks - 6
8. Natural White - 1

The chemical nature of natural dyes is quite complex. They have a mixture of closely related chemical compounds and not a single entity as in case of synthetic dyes. Sometimes it becomes very difficult to characterize the main colouring component in the dye source. Generally the source contains only 3 to 5 per cent of the major dye component in majority of the natural dye sources. Based on the major colouring component present in natural dyes, they are classified as

1. Anthraquinone dyes
2. Indigoid dyes
3. Carotenoid dyes
4. Flavonoid dyes
5. Dihydropyran dyes
6. Tannin-based dyes

To characterize the dye component in natural dyes, advanced testing equipment are required such as High performance Liquid Chromatography (HPLC), Thin layer chromatography (TLC), High performance Thin Layer Chromatography(HPTLC).

Besides being biodegradable and eco-friendly, natural dyes are advantageous as they produce shades that are soft, lustrous, and soothing to the human eye, range of colours by mix and match system, produce rare colour ideas, generally renewable, pose no disposal problems, potential to earn carbon credits, non-hazardous in nature, bleed but do not stain other fabrics, provide curative, antimicrobial, UV protective, antiodourant properties.

The limitations found with the usage of natural colours are light shades, fair colour fastness, shade variation, difficulty in reproducibility of shades etc. These are the factors at large that imped the expansion of natural dyes in textiles and other enduses.But with the advancement of technology, the limitations are being addressed especially for dyeing cotton and other cellulosic textiles for which the substantivity of natural dye is less. The natural dye shades obtained on wool and silk are brighter as natural dye show better substantivity towards protein fibres.

Natural dyes may be applied on cotton and other textiles at fibre, yarn, fabric and garment stages. Among all, fibre dyeing may be more effective, but very cumbersome and costly affair. So yarn dyeing is preferred over other methods of dyeing. Fabric and garment dyeing has to be carried out carefully, otherwise, it may end up in patches.

Production of natural cotton dyed textiles at large scale is challenging as the limitations of the natural dyes need to be addressed.

Sustainable supply of raw material to the industries : India is bestowed with large number of plants/ trees that can give rise to natural dyes required for textile industry. Often the availability of raw material is debated in many natural dye forums as we have not yet planned how to meet the natural dye requirement. Natural dyesources are obtained mainly from plant/trees and partly from insects and minerals. These are either cultivated or collected from abundant forest base. The cultivated varieties are very few such as marigold, indigo, safflower, annatto, etc. rest of the varieties are generally collected. This is again governed by limited awareness about these sources and unorganized market sector. Eventhough, lot of natural dye sources are found in forests, only few are being collected. Some dye bearing plants/trees are location specific and are found only in few areas. Utilization of these sources by the textile units of that location may be more economical than sourcing it from other states/ areas. Moreover, the cultivation of natural dye sources may become viable alternative for farmers. Geographical mapping of these sources needs to be taken up to help in sustainable supply of raw sources.

Another idea of generating the sources may be from food, beverage and timber waste. Industrial production of food and beverages generate huge waste and by-products that are rich in natural pigments. For example, onion skin from food industry, pomegranate rindfrom beverage industry, barks and saw dust from timber are very valuable sources of natural dyes. Flowers such as marigold is a very rich source of yellow. This can be systematically collected from temples, function halls during festival and marriage seasons.

Management of bio waste : Extraction or dyeing with natural dyes leaves the bio-mass equal to the raw source as only colour is extracted and the source volume remains the same. Space is a constraint everywhere and disposal of this waste may be a problem. Among the raw sources, soft and hard material exists. After extraction of the colour, soft sources such as flowers, leaves, fruit rind etc. can be used for making a bio-fertilizer and hard material such as barks, wood, roots, seeds etc. becomes excellent raw material for making brickets for fuel purpose. The bio-waste can be sold to those who are involved in manufacturing of brickets and bio-fertilizer.

Low colour content in sources : Natural dyes possess less intensity than the synthetic dyes. Around 0.5 to 5 per cent colour content (colouring substance) is present in natural dyes which is very meager as compared to synthetic dyes wherein the active ingredient ranges from 22 to 78 per cent. Accordingly, large quantity of dye source is required for commercial application. Biotechnological interventions are underway to improve the pigment content of the selected varieties of natural dye sources such as marigold, madder, indigo etc.

Machinery for dyeing with natural dyes : Dyeing cotton and other cellulosic fibres with natural dyes involvesextra preparatory steps such as treatment with tannins and mordants before dyeing. It needs extra processing, time and other resources. In case of silk / wool dyeing, treatment with tannins is not required as the fibres do possess better substantivity to natural dyes. Most of the natural dyes need high temperature upto 80^{0} to 90^{0}C. Indigo can be dyed at lower temperature of 60^{0}C. The yarn or the fabric must be in contact with the dye upto 45 minutes at the selected temperature. Slight pressure if applied during dyeing will improve its absorption and helps in achieving dark shades. Therefore, the machinery for dyeing yarn / fabric should be selected based on the above factors. Different types of yarn dyeing machines are available today. Hank or cone/ cheese dyeing machines can be selected with slight modification to suit natural dyeing. Jigger dyeing machines are successfully used for dyeing woven fabrics. These machines provide low material to liquor ratio and are suitable for dyes having low exhaustion such as natural dyes. Soft flow dyeing machines are apt for dyeing knitted fabrics.

As dyeing with natural dyes involves a greater number of steps than synthetic dyeing, mordanting and wash cycles must be carefully planned and executed.

Inadequate fastness : Improved methods over the conventional methods of dye extraction and dye application on textiles are established by the research groups internationally. The reasons for low exhaustion of natural dyes have been studied and analyzed. To address this problem, improved extraction and dyeing methods and organic dye fixing agents are developed. Due to this, it is possible now to obtain good fastness on textiles dyed with selected natural dyes.

High dyeing costs : As the process of dyeing with natural dyes is lengthy and involves additional steps such as dye preparation, extraction and mordanting, the energy costs coupled with labour are added to the dyeing costs and make it more expensive than synthetic dyeing. Pure natural dye powders are highly priced, sometimes more than the cost of vat dyes. The dye source contains only meagre amount of colouring component, and huge amount of source material is required for dyeing unlike synthetic dyes whose intensity is high. If source is used for dyeing, the costs of its preparation and the amount of source material to be used, its transportation and disposal will be added to the dyeing costs.Eventhough, dyeing with synthetic dyes is more economical, the costs of effluent treatment are more as compared to natural dyes and the final price may almost be equalor little above. Natural dyed textiles are sold at a premium price in terms of the advantages of natural dyes for environmental wellbeing and that compensates the high dyeing costs.

Quality certification for natural dyes : Enormousresearch has been carried out so far on natural dyes, but very little is known about the chemical nature of the colouring compounds. Quality checking of natural dyes is not done authentically and no controlling body for certifying natural dyes is present. Although, GOTS (Global Organic Textile Standards) certifies natural dyes at present, it is not sufficient to control the counterfeit textiles appearing in the market. There should be national and international governing bodies that must be established to certify natural dyed or printed textiles within the reach of manufacturers and consumers.

Eco-friendly mordants for application of natural dyes : The metallic mordants other than alum and ferrous sulphate are not eco-friendly and their usage in large quantities may harm the environment. Mordants such as tin, chrome and copper should be judiciously used as part of these mordants remain in the effluent water and needs to be treated. Therefore, research should focus on investigation of eco-friendly mordants that can give bright fast shades on textiles.

Reproducibility of shades : One of the major drawbacks of natural dyes is the difficulty in reproducing the shades. As it is very important in textiles made at large scale, much focus is being laid on this aspect. Generally, natural dye sources vary as per the season, part and age of the plant and the agroclimatic conditions. They are also pH sensitive. Due to these conditions, the dye material concentration varies and create difficulty in shade matching. Natural dyes in pure form are available in the market today, which can address partially the problem of shade reproducibility. But careful planning coupled with controlled dyeing skill enables the industry to overcome the problem.

Effluent treatment plants (ETP) : The dyeing with natural dyes does not involve many chemicals as in case of synthetic dyes, there is no need to establish high end ETPs and the cost involved in treating the metal mordants may be very economical. Separate standards for natural dyes do not exist in India at present, but in future, it is expected to establish new standards for natual dye ETPs.

CONCLUSION

In the interest manifested in environmental well-being, natural dyes are preferable for dyeing and printing textiles. Inspite of few limitations, natural dyes produce very positive and bright shades on natural fibres. The growing popularity for eco-friendly textiles has created unstinted demand in the market. Due to high export potential for these products, India with its vast resource base should encourage big players to augment production at large scale. Mechanization in this field is inevitable and research should focus on these aspects.

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Integrated weed management in cotton in India

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ABSTRACT : India has the largest area and production of cotton in the world. After the adoption of Bt cotton, India's cotton acreage and yields increased by a fifth between 2005-06 and 2016-17, though in 2017-18productivity was 9% lower. With 12.9 m ha area, it is forecast that productivity for 2019-20 will be 15% higher. Gujarat, Maharashtra,Telangana, Karnataka, AP, Haryana, MP, Rajasthan, Punjab and Tamilnadu are the top ten cotton producing states of India. The average cotton productivity in India is much lower due to adopted cultivars, cultivation conditions, and onslaught of insects-pests, including weeds. Due to wide spaced crop with slow initial growth, weed are potent enough to lower yield from 10 to 90% depending upon weed management practices. With technological innovations the present day agriculture is embracing efficient management system to meet the ever increasing population demand of food fibre and fuel. Under these conditions it is utmost important to lower the cost of cultivation and increase yield under an integrated weed management system which include crop diversification, cultivars competitiveness with early vigour, crop geometry (narrow row plantation) rows orientation to sunlight. The agriculture sector is embracing energy efficient conservation systems and technological innovations to meet the ever increasing demand for food, fibre, and fuel in tune with the rapidly increasing human population.Undoubtedly, integration of non-chemical methods and diversifying weed control options would ensure the sustainability of available weed management options, including herbicides. Increasing crop competitiveness is one of the approaches that could be integrated with the current weed management systems. Choosing cultivars with early vigour, use of narrow row planting, orienting crop rows with regard to sunlight, planting time, irrigation and fertilizer application time, and adjusting planting density are some of the agronomic approaches that could enhance the competitiveness of cotton over weeds. Conservation agriculture (stale seedbed, zero tillage use of non-selective herbicides before planting, moisture conservation, adoption of nano-fertilizer pellets, mechanical/manual weeding, mixed cropping, use of mulches (plastic, dust and trash), biological methods and application of weed biology knowledge is vital for an integrated approach. Though herbicides alone may not be sustainable in the long run, but any weed management approach is

incomplete without them. Application of pre-plant incorporationherbicides (ethalfluralin, pendimethalin, alachlor), pre-emergence (pendimethalin, trifloxysulfuron, alachlor, oxyfluorfen), post-emergence (alachlor, pyrithhobac-sodium, trifloxysulfuron, diuron, clethodim, propaquizafop,quizalofop-ethyl, fenoxaprop-p-ethyl),post-directed (paraquat, glyphosate, glufosinate, oxyfluorfen), directed herbicide mixture (trifloxysulfuron + pyrithiobac + fenoxaprop-p-ethyl, pendimethalin/oxyfluorfen + paraquat/glyphosate)can be used as per weed infestation and application time. It is desired to rotate herbicides and crops for avoiding dominance of a particular weed species or evolution of resistant weeds to herbicides.

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Innovative approaches in breeding cotton

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Historically cotton is valued as a highly remunerative crop and at the same time it is haunted by very complex and voracious pests which constantly affect to diminish remunerative value of cotton.Sometimes tere is compounding effect of problems of biotic stresses namely bollworms sucking pests and viruses and they are quite capable of overcoming the barrier of resistance and add new dimensions of hostility.Anoter bigger problem of cotton cultivation in Indian subcontinent is that here there are no afforts made to reduce dependence on labour for cultivation of cotton unless it is made less labour intensive and bring mechanized cultivation it may become difficult to cultivate cotton against te lower cost of cotton cultivation in many countries where machines take care of cultural operations. In the years to come breeders have to address remunerative value as a priority trait rather than productivity.

The inevitable path to reach this goal will be to reduce radius of cotton plant type and determine optimum height thus making the plant type ideally suited for machine picking apart from suitability of plant type for use of machines for sowing, for weeding spraying and such other forms of mechanization.

Conventional breeding methods are easier in execution and cost lesser cost as compared to genetic gain and improvement in productivity and other traits achieved through these approaches. However due to lack of sufficient knowledge of principles governing genetic basis of creation of variability and its exploitation these crucial steps are defectively planned and executed thereby reducing the genetic gains/ extent of improvement. Hence it is essential to acquire thorough knowledge of the genetic basis of plant breeding so that sufficient positive variability is created and it is exploited trough selection or heterotic populations are developed and hybrids are derived .

This knowledge also helps in introducing situation dependent innovative approaches in planning and execution of different schemes of genetic improvement and hybrid development. Since the technique innovations have high commercial value now a days we observe that breeders especially from private sector don’t disclose their knowledge on procedures and innovations in breeding approaches. In the modern era innovative approaches in breeding, knowledge about developing an using new male sterility system , steps of transferring male sterility, development and transfer of new GM events, registration issues of lines are coming to light, innovative procedures of hybrid development, use of testers procedures of heterotic grouping and its exploitation, hybrid development approaches are all becoming trade secrets and new modifications ,simple tools procedures or tools are never discussed in public and this is not good in the interest of growth of plant breeding . These hurdles need to be overcome to encourage healthy development of the science and art of plant breeding.

Breeders work in situations which show wide variation in terms of strength of resources measurable in terms of availability of team of scientists required for selecting genotypes for stress tolerance to screening for quality determining physiological parameters , bio mass and harvest index values etc.,. There are wide differences in terms of facilities available to screen the segregants for pest tolerance, disease resistance and creation of artificial epiphytotic conditions to screen for disease resistance.It may mean availability of offseason facility, management of the crop, recording observations on important yield contributing characters even in a resource stricken location, individual breeder, makes his own crosses and the efforts required for choice of diverse and complimenting team of parents creation of wide range of diversity and handling such huge variability can not be managed by individual breeders It is hence necessary that concerted efforts are made through national level or state level network programs of building broad based segregating populations and distributing them to involved breeder and even assisting team of breeders in exploiting segregating populations for practicing selection at each location , exploiting such populations for bringing about genetic improvement.

Often the breeders efforts are aimed at simultaneously improving number of productivity, quality, resistance to stresses, etc.,. and this amounts to overall genetic improvement of all traits of productivity and value addition in each segment of commercialization. In fact were improving yield itself means covering traits related to biomass, harvest index each influenced by array of traits. Is breeder selecting parents which perfectly compliment for all these traits? Can he expect just two parents which compliment one another perfectly for tis array of traits?Its very difficult to expect a pair of two parents to be perfectly complimentary for so many traits.If the two chosen parent s are differing for few characters ,variability released will also be limited to that extent.

Genetic improvement of cotton is aimed at developing improved varieties and potential hybrids and a sound knowledge of genetic basis of success in various stages of genetic improvement. An absence of this leads to oversimplified procedures and defective execution of steps at different phases of varietal improvement. Due to this though the amount of time and energy involved in the procedures of creation of variability and its exploitation remains same realized genetic gains produced by breeders remains low This paper dwells on explaining genetic basis in deriving modifications in conventional breeding methods. It shows how is necessary to extend some principle steps of breeding cross pollinated(random mating system) crops and blending them with routine procedures of self pollinated crops to improve the efficiency in genetic improvement of cotton for both varietal and hybrid development. Where ever possible, outcomes of our own research findings is summarized and presented in support of the concepts and at some places modifications in procedures /steps are suggested based only on explanation of genetic basis of the innovative approaches. and modifications in steps of cotton breeding .

There is a clear lack of research in plant breeding system and procedures of varietal improvement or hybrid development. Attempt is made in this paper to draw attention of cotton researchers to findings emerging from our plant breeding system research and also some inferences and plant breeding implications derived from principles of Population and Quantitative Genetics .

Parental genetic complementation : The key to creation of useful variability : Suceess of varietal improvement depends up on the magnitude of useful variability released for large number of yield,fibre quality stress tolerance related traits followed by its efficient exploitation through selection. Desirable variability for an array of these traits will be released only when the parents chosen for hybridization are genetically diverse enough to compliment for all these traits and as a result the F1 segregates for these large number of loci . Choice of team of parents for hybridization can be effectively done by assessing the score card of a genotype for an array of requisite traits and decide up on the group of parents which as a team compliment for entire range of traits. It is difficult to expect just two parents to perfectly compliment each other for the entire range of yield components either influencing biomass or translocation of photosynthates to sink biotic, abiotic stress related traits and an array of other desired traits.

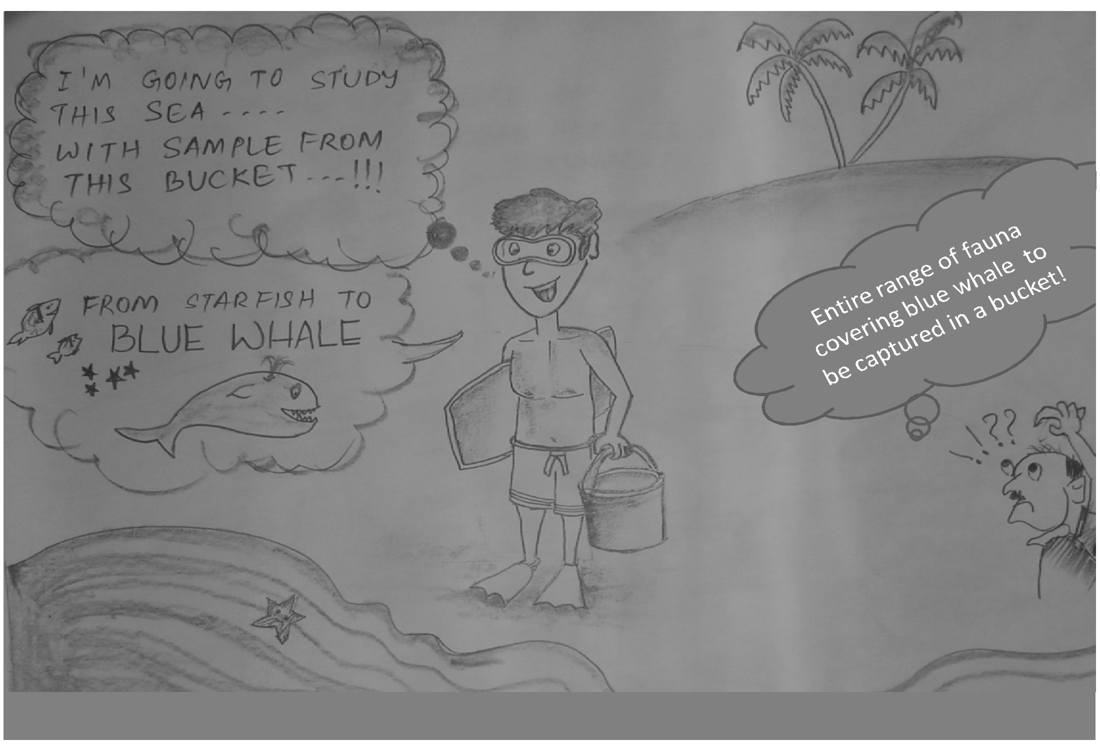
In one of our studies variability was studied in different combinations of four carefully chosen diverse parents representing genetic diversity is compared with that based on two parents. For this purpose four parents were used from the proven plant type diversity groups like robust stay green types on one side and high relative growth rate types and also the compact types on the other . It is observed that proportion of transgressive segregants is much higher when such four based segregating populations are developed for practicing selection in segregating generations(Edke2016). Efficiency of releasing useful variability improves when multiple parents accounting for the desirable expression for an array of characters are used as they account for better complementation of an array of important traits as compared with use of just two parents. These results clearly indicate that for effective varietal improvement(genetic gain) in cotton, the existence of diversity of parents and complementation for the entire range of traits is very essential.

Effective modifications in approaches of handling segregating populations : After creation of useful variability the next dimension of factors is exploitation of the variability created through hybridization. For this it is essential to recollect some basic concepts of consequences of selfing

Consequences of Selfing and Constitution of selfed generations: Simple Mendalian expectations of segregation at a locus form the basis for determining the constitution of plants in the segregating populations derived through selfing. A heterozygous F_1 segregates to give 2^n gametic types and Error! Not a valid link.Error! Not a valid link.Error! Not a valid link.Error! Not a valid link.Error! Not a valid link.3^ngenotypic classes As the number of loci influencing the ultimate dependent character like yield goes on increasing, values of total number of genotypes produced in F_2 generation reaches astounding figures.

Breeders should distinguish between minimum population size and optimum population size to be raised in F_2 genearation. It is interesting to iknow how this minimum expected population size changes over different segregating generations.When an F1 segregates for a meager 21 loci over 2 million gametic types are produced by $F_1$and when these gametes unite, 10billion genotypes s are produced and this demands a minimum population of 4trillion plants raised in F2 generation and this is far less than . the optimum population size required to be raised for these many loci Though Allard(1960)addresses the issue of minimum population size no mention is made about the optimum population size required to be grown.It is difficult to get and utilize the land even when F_2 of cotton is segregating even for 21 loci? If a realistic number of loci (hundreds) governing inheritance of a dependent character like yield are considered, the genotypic classes and minimum population size reach astronomical figures and the population size normally used for handling F_2 segregating generation becomes abysmally low to capture the variability. If the entire range of variability is not captured it is difficult to expect the most potential genotypes to be seen in small population raised by a breeder The cartoon shown in the figure highlights how small population size becomes just incompetent to capture the full range of variability released in F_2 generation obtained from a cross of truly diverse parents(segregating for hundreds of loci.

There are no studies conducted on the



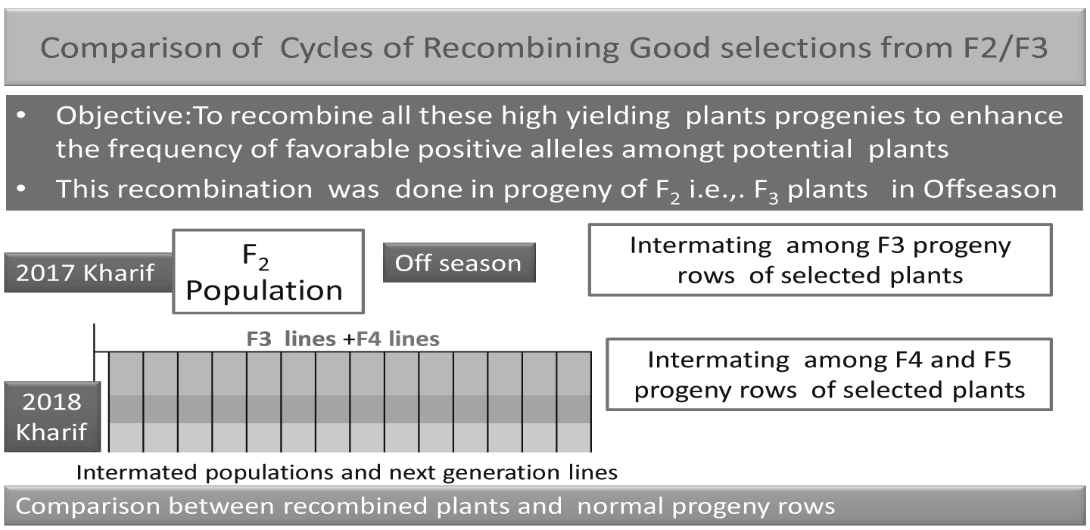
minimum F_2 population of cotton to be raised and the impact of small sample size on the reduction in observed variability and loss of transgressive segregants in the normal size of few hundred plants.In our study a comparison of variability and frequency of transgressive segregants out of 2000 plants is made by taking a random sample of 200 plants each time out of this reasonable F_2 population. The data has shown how the most potential plants are often missed when small population size is examined.

As an outcome of this study it is suggested that whenever diverse parents are used in hybridization and large amount of variability is released , individual breeders are not capable of handling such large F_2 populations and capture the most potential transgressive segregants . If such crosses are shared among breeders so that as a team they manage to evaluate large F2 population and the most potential transgressive segregants are captured by the team of breeders. In fact one of the areas of research could be on what happens when the F_2 population is shared and distributed to number of breeders /locations so that its true potentiality is realized somewhere by some breeder rather than just one breeder creating huge useful variability but ultimately smothering the transgressive segregants by not growing them! There is a need for developing yardstick for determination of the acceptable optimum population size based on the visible diversity among the parents for different yield related traits. Many of the problems of cotton are too serious to be tackled by individual breeders and call for initiation of national level programs aimed at concerted efforts of team of breeders ,entomologists/pathologists etc.,. so that the seeds of the broad based populations developed in this manner are distributed to individual breeders.

The minimum population size reduces from 4^n in F_2 to 2^n by about F_6 or so. This opens up possibilities of series of modifications of handling selfed segregating generations.Even if selection is postponed to F3 by raising F_2 in off season by giving very close spacing the minimum population size reduces roughly to 3^n in F_3. This amounts to a big advantage in terms of increase in the chance of getting the most potential transgressive segregants. These implications are of general value in all self pollinated crops and cotton breeders should make use of these findings by exercising care in handling segregating generations. It is essential that breeders exercise modifications in procedure of handling segregating generations and a team of subject experts should help them in determining the situation dependent modifications in procedures of handling segregating generations to ensure higher success rate.It is a harsh reality that the breeder equipped with sound knowledge of genetic basis of cotton breeding can produce much more efficient improvement as against an ignorant breeder even if the two are handling the same population for developing a variety or the same Germplasm for developing a hybrid!

Innovative steps to recover the invisible most potential transgressive segregants! : The genetic explanation amply convinces the fact that just as the blue whale is missing in the bucket of the breeder the most potential transgressive segregants are missing from the small F_2 population.Now the condition of the cotton breeder is comparable to the fate of the passanger heavily loaded with luggage reaches the railway station just to discover that the train has already left the station.The challenge of catching the missed train should be compared with the challenge of creating the invisible most potential transgressive segregants.

In understanding the genotypic constitution of the available potential segregants it is worked by the author that if the F2 population is sufficiently large (say thousands)the visible most productive segregants carry many of the desirable alleles distributed among them. This is comparable to the bits and pieces of a beautiful face in a zig zag puzzle. Only when recombine the productive segregants it is possible to recreate most potential segregants which are missing in segregating generation because of the small population size raised in early segregating generation.



In a study conducted on segregating F_2 generation of *G hirsutum* varietal cross, the top 20 plants were advanced to F_3 in off season and recombined through simulated random mating and the recombined population resulting from churning the genetic back grounds of these progenies was evaluated along with the normal selected plants progenies of the cross.The mean, variance and frequency of transgressive segregants observed in this churned(recombined) population was found to be improved over the just selected for high yield and the random population.This highlights the need for a mandatory step of recombination among the available potential segregants in early segregating generation to generate the missing most potential transgressive segregants.

Genetic basis of some more modifications: The minimal population size by F_6 generation reduces from 4 to 2 per locus and this gives an advantage running to billions for this scale of segregation and hence this can be a blanket advantage of SSD over pedigree/ bulk methods of breeding. There is immediate attention required on comparing efficiency on SSD over other methods in terms of reduction in minimum population size. Instead of following SSD atleast in F_2 by utilizing the off season and growing F_3 to start selection for the first time .Just by postponing artificial selection to F_3 the minimum population reduces to 3 per locus and this means a big advantage considering large number of genes for which the population is segregating.

Genetic basis of back crossing: The similarities and differences of consequences is an interesting area of theoretical research. The detailed studies carried out by the author has revealed interesting facts based on the constitution of segregating populations as compared to constitution of back cross derived populations. The proportion homozygous genotypes is equal to proportion of plants resembling recurrent parent.Hence proportion of plants exactly like recurrent parent" is still very less in even BC_5 generation.Its the proportion of plants "nearly like recurrent parent that becomes more than 90% of the BC_1 population

By deciphering similarities and differences in consequences of selfing and back crossing it is possible to show that the size of back cross populations normally involved in backcrossing is very small and this can also adversely affect the recovery of constitution of back cross derived generations.The minimum population size is 2^n in BC 1 generation and considering large genetic back ground this becomes a very large population unlike the commonly used size of BC1 population used for back crossing. It works out to be 2 million plants if the genetic back ground is definable by just 21 genes. If realistic assumption are made on genetic background of recurrent parent populations due to sampling effect and it can slow down recovery of constitution of recurrent parent. The implications of these findings are that number of plants carrying the trait under transfer from donor parent have to be large and indeed this becomes the BC population which must account for the entire range of variability released in the population.This explains why many a times we fail to recover the constitution of recurrent parent of cotton while transfering Bt genes or genes for resistance traits etc.,.

Concept of Target genotype and studies on determining target genotype: When hybridization work involving the chosen parents is initiated breeder should have a clear perception of the constitution of the most potential transgressive segregant (aimed to become constitution of the new variety). The idea is to define such a genotype as **"Target Genotype"** in terms of the proportion of alleles retained from the two parents chosen for hybridization(it can be defined in terms of multiple parents as well but for simplicity, the case of using only two parents in hybridization is considered). The perception of Target genotype should be clear to the breeder and this enables the breeder to choose right option of breeding method and even make alteration in handling the segregating generations.

After hybridization the varietal breeding methods of handling genetic material after hybridization can be broadly grouped in to a)Pedigree/ Bulk/ Single seed decent and b)

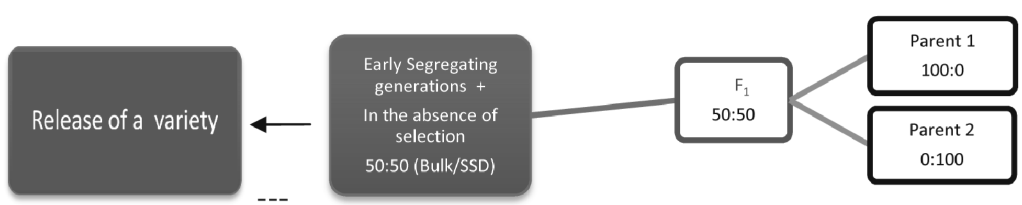
Back cross method of breeding. This distinction between the breeding methods can be made in terms of the proportion of alleles of the two parents (involved in crossing) seen among the segregants in the generations derived (after hybridization) in these methods of breeding. Back cross method of breeding is used when the donor parent has highly undesirable genetic background except for one desirable simply inherited trait (Allard, 1960). In terms of proportion of alleles required from the two parents, the target genotype would be defined may be as 98:2 or 99:1. The genetic consequences of back crossing and about when to use Back cross breeding, are well explained in different books on Plant Breeding and the procedure followed during back cross breeding precisely increases the chance of occurrence of such a targeted genotype.

Backcross method of breeding is considered as unique and scientific especially because this breeding procedure facilitates and enhances the chance of occurrence of the targeted genotype (something like 99:1 in terms of proportions of alleles from the two parents) by modifying constitution of the base F_1 population(with 50:50 allelic proportions of the two parents) developed through hybridization. In every backcross generation, the proportion of alleles from the recurrent parent goes on increasing and the undesirable alleles of donor parent are flushed out at high speed. If the breeder keeps track of the desirable trait of the donor parent under transfer and holds that intact in the plants chosen for back crossing, the targeted genotype is produced with great ease.

In Pedigree/Bulk/SSD? Is it possible to expect a high frequency of this target genotype? How do they compare with Back cross breeding

Methods of Varietal Breeding and proportions of alleles from the two parents commonly seen among the segregants:

I) Selfed Generation method (Pedigree/ Bulk /SSD Method)



II) Release of a variety

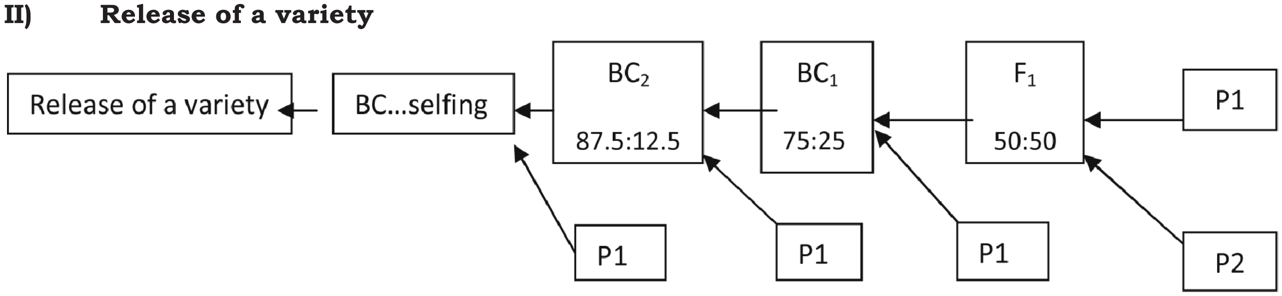


Fig 1. Procedures of Handling the Material after hybridization in Varietal Breeding of Self pollinated crops and the proportion of alleles from parents

methods in terms of efficiency in generating high frequency of the desired target genotype? Should these methods be rated as less scientific because the target genotype set is not often achieved? Depending on the need can these methods be made more scientific (target oriented) by blending the steps of selfing and backcrossing to increase the efficiency in creating high frequency of the target genotype? These are the important aspects on which lot of information has to be generated through breeding system research but there is a dearth of planned research in this direction.

In the entire population of plants in a segregating generation , the average proportion of alleles of the two parents in $F_{1,}$ F_2 and any subsequent segregating selfed generation is 50:50. It has been worked out and shown (Patil 2015) that when each plant's genotype is examined in terms of alleles contributed by the two parents and the frequency distribution is worked out, it is observed that the proportion of plants with allelic contribution being equal to close to 50:50 is highest.When this explanation is extended to cover polygenic traits the distribution assumes the shape of normal curve.The inference derived from this distribution is that all the three procedures of handling segregating generations(pedigree,Bulk and SSD) will be successful when the desirable alleles for all the loci are distributed equally among the parents used for hybridization.It also means that if the distribution of desired alleles is uneven pedigree method of breeding will not be successful As against this , in backcross breeding, the proportion of alleles from recurrent parent goes on increasing with every backcross generation .This is always seen as a major difference in the consequence of selfing and backcrossing. The very purpose of back crossing is to decrease the proportion of alleles of the donor parent which is found to have a bad genetic back ground. With continuous backcrossing there is a methodical increase in the proportion

Table 2: Proportion of alleles of two parents among segregants of

a) F_2 generation.

	Genotypes and Proportion of alleles of two parents				
One gene case	AA		Aa	Aa	
Proportion of alleles of parents	100:0		50:50	0:100	
Segregation ratio	1		2	1	
	Genotypes and Proportion of alleles of two parents				
Two gene case	AABB 1	AABb 2 AaBB 2	AaBb 4 AAbb 2 aaBB 2	aaBb 2Aabb 2	aabb 1
Proportion of alleles of parents	100:0	75:25	50:50	25:75	0:100
Segregation ratio	1	4	6	4	1

b) F_6 generation.

	Genotypes and Prop of alleles of two parents		
Two gene case	AABB 1	AAbb 1aaBB 1	aabb 1
Proportion of alleles of parents	100:0	50:50	0:100
Segregation ratio	1	2	1

of plants (in back cross population)which resemble the recurrent parent.

The segregants most commonly observed in a breeding approach should match with Target genotype set at the beginning of the varietal improvement program. Otherwise the selected approach may not give the desired result. Hence it is necessary to understand what is the target genotype set by the particular pair of parents before embarking on choice of breeding procedure. It is also equally important to understand what are the types of segregants most commonly observed, in a selected breeding approach.A segregation ratio of 1:2:1 is observed in F_2 generation with respect to a locus under consideration. As shown in Table2 when segregation at two loci is considered, a ratio of 1:4:6:4:1 is observed where the segregants with 50:50 allelic contributions from the two parents are most commonly observed. The extreme types and those with unequal contribution of alleles from the two parents are not commonly observed. Extending it to the case of three loci, a ratio of 1:6:15:20:15:6:1 is seen in F_2 and here again segregants with 50:50 or nearly 50:50 allelic contribution from the two parents occur most commonly in an early segregating generation. This pattern of segregation remains same even when large no. of loci affecting a quantitative character are considered and this is depicted in Figure 1 and 2. Both in Bulk and SSD methods , artificial selection begins at a stage when population is fixed or nearly fixed at the segregating loci governing inheritance of quantitative traits(may be F_6 generation signifying the fixation of genotypes) and at this stage number of gametic classes and genotypic classes are same(2^n). With the help of Pascle’s triangle, the segregation ratios can be worked out in F_2 generation and also in the generation representing fixation. The trend of prominence of 50:50 types among segregants continues even at this stage of fixation. It means that whether it is pedigree or bulk or SSD method of handling segregating populations,50:50 types of segregants are most commonly seen in these populations subjected to artificial selection. As compared to this there is a lower frequency of 70:30 types (or symmetrically 30:70 types) and a still lesser frequency of 95:5(or 5:95) type. It is important to remember for this reason that the target genotype achieved through back cross method of breeding (say 98:2type) is very much available even in F_2 generation but locating such segregants in F_2 becomes a Herculian task and hence it is avoided and the tedious procedure of continuous back crossing is preferred to selecting for the target 98:2 type in F_2 or later segregating generation.

Thus selection practiced in these segregating populations will be successful only if the Target genotype set by the pair of hybridized parents is close to 50:50. This means that if the two parents are perfectly complimenting each other on gene for gene basis or crudely speaking trait for trait basis (component trait) basis, the target genotype set will be 50:50 type. In simpler terms, in any segregating generation (F_2, …F_6.), the segregants which are 50:50 types (50% alleles from each parents) are the most commonly observed types. If the two parents are complementing each other perfectly by sharing the desirable alleles each at 50% of the total number of loci responsible for yield then the target genotype in case of the parental pair chosen for hybridization is a 50:50type. Since the segregating population consists of mainly 50:50 types the job of the breeder is restricted to selecting the **"Best 50:50 type"**. This ultimate best 50:50 type is the Target recombinant type and incidentally it is a positive transgressive segregant which blends the desirable favorable alleles equally distributed between the two parents. Among this wide array of 50:50 types of segregants, one can also expect extreme positive transgressive segregants described above and also an extreme negative transgressive segregant perfectly blending only the undesirable alleles distributed equally between in the two parents. Since the population has high frequency of 50:50 types, selecting the best 50:50 among them becomes relatively easy. Based on this theory, just as it is expected that these three methods of handling segregating populations after hybridization will be successful when the target genotype is a 50: 50 type it should also be remembered that following these methods will be an ineffective attempt (if not a wasteful exercise) .

If the parents used in hybridization reveal un equal distribution of desirable alleles(traits) between the parents (say 70:30 or 80:20). It is because frequency of these types in early or later segregating generations is very low. Searching for the best 80:20 in a population full of an array of 50:50 types and a very low frequency of these different 80:20 types is perhaps equivalent to search a pin in a haystack .Very often the breeders fail to find potential transgressive segregants in the segregating generations but how often do they correctly understand that the main reason for failure is that the method of handling the material after hybridization is wrong?

The methods of handling segregating generations are well defined when the target genotype is 50:50 type (Pedigree/ Bulk/ Single seed descent method) or an extreme type such as 99:1 or 98:2 or 100:0 (Back cross breeding). When the target genotype is in between these two, say 70:30 or 80:30 types there is a need to go for limited back cross breeding. In a single back cross derived populations (BC_1F_2, BC_1F_3... etc.,) 75:25 types are most commonly observed and hence it is easier to expect higher frequency of 70:30, 75:25 or 80:20 types .Here again, the job of the breeder is simplified to the extent of finding which 75 are seen from the first parent and which 25 are seen from second parent. When majority of segregants are 75: 25 types, it becomes easy to pick up the extreme positive transgressive segregants with the required desirable 75 alleles from first parent and 25 from the second parent.

Thus, selection in limited back cross derived population would be successful whenever the parents reveal unequal distribution of desirable alleles between them(say around 75:25) while selfed breeding methods will be more efficient when parents reveal nearly equal distribution of desired alleles between them . The utility of limited back cross approach of breeding has been highlighted earlier by Patil (2007,2011).

Back cross derived Pedigree/Bulk/ Single seed descent method: It is important to note that limited backcrossing just refers to creation of base BC_1F_2 population with higher frequency of the target genotype. Once such base population is created, breeder has many options of initiating artificial selection right in BC_1F_2.

This modified approach is similar to pedigree method of breeding and can be continued by implementing selection schemes described for F_3,F_4 etc.,.in corresponding BC_1F_2,, BC_1F_3,etc.,.respectively.The back cross derived population still has considerable heterozygosity and if this is considered as a disadvantage, artificial selection can be delayed up to BC_1F_5 when the proportion of homozygous plants is increased substantially. Either bulk method of advancing or SSD approach can be followed through these early segregating generations. There is a need for research on comparing efficiency of following Pedigree/SSD/Bulk methods in handling segregating generations derived through limited back cross breeding

Following approach of determining target genotype involves comparison of back cross Populations to P1(B1) and P2(B2)with F_2 population.The segregation pattern seen in B1, B2 and F_2 populations shows differences in prominent types namely 75:25,50:50 and 25:75 types in them. This becomes genetic basis for explaining differences in means of these populations. If the target genotype set by the pair of parents involved in hybridization matches with prominent segregant type seen in a generation the mean performance of that population will be higher than the remaining two populations. As per this basis of inheritance any of the following three situations shown in can be seen in an evaluation study where these three segregating populations are compared.

Improving potential of Compact cotton : Increasing labour cost is reducing the remunerative value of cotton At present most of the cotton cultivated in Indian continent is robust in nature and cultivation of such types is becoming highly labour intensive .The increasing labour cost in cotton cultivation has reduced remunerative value of cotton and it has become necessary to alter the plant type and make it as compact as possible so that the benefits of compact cotton plant types can help in tackling these emerging problems of labour cost, increasing pink boll worm incidence and reducing remunerative value of cotton.Compact cottons have primary advantage of planting in high density contributing to high yield coupled

Table 3: Comparison of means of segregating populations

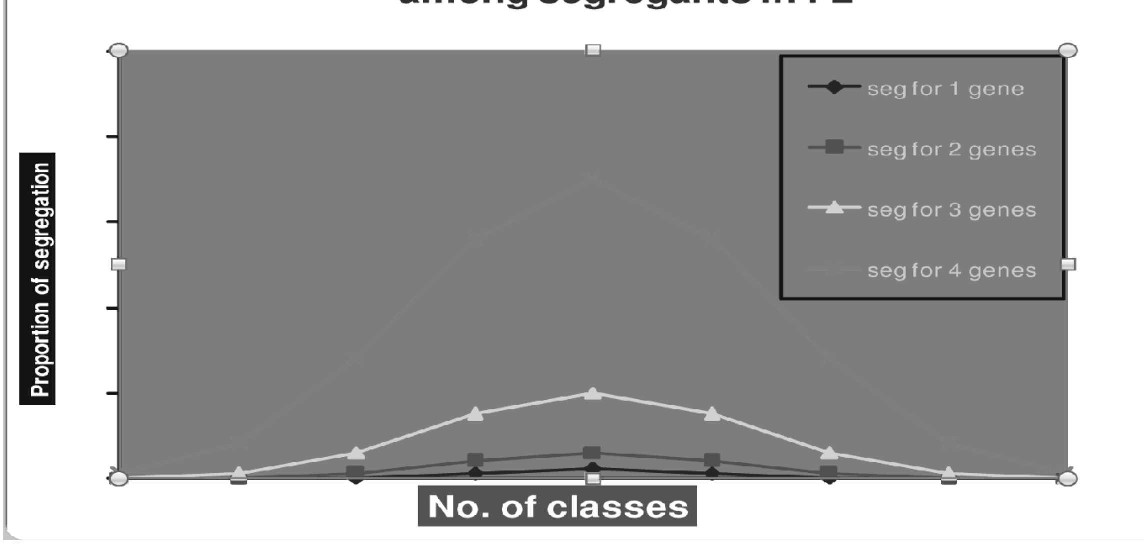
Situation I : Decreasing order of performance being B1>F_2>B2 Here P1 parent has higher proportion of desired alleles contributing to higher productivity and as a result of this the decreasing order of performance of populations will be B1>F_2>B2. In such a case selfed generations of B1 populations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding
Situation 2: Decreasing order of performance being B2 >F2 >B1
Here P2 parent has higher proportion of desired alleles contributing to higher productivity because of which these populations reveal a decreasing order of performance of B1>F_2>B2. In this situation, selfed generation of B2 populations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding.
Situation III: Decreasing order of performance being F_2>B1 or B2 .
Here P1 and P2 parents have equal proportion of desired alleles contributing to higher productivity of F_2>B1 > B2 or F_2>B2 > B1. In this situation advancing selfed F_2 and later segregating generations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding.

with simplification of cotton cultivation,being plant protection efficient , reducing the intensity of pink boll worm damage ,amenable for one time picking preferably by machine and till such time convenient even for manual picking Under irrigated conditions compact cotton varietries provide room for double cropping leading to diversity in cropping system and crop rotation which are need of the hour in cleansing cotton ecosystem and reduce the risk of pest dominance and development of resistance.

There are some priority areas of genetic improvement in compact cotton improvement. Studies conducted by us on blending fibre quality with compact lines through use of multiple parents has lead to simultaneous improvement in productivity ,fibre quality and boll size coupled with features of compactness . It has been possible to bring compactness even in hybrids Use of super compact parents against tall compacts have given rise to tall compact hybrids which record high productivity under close(3X1feet) spacing due to increase in density. These findings show that there is a clear possibility of reducing stature of varieties as well as hybrids. However the stature of varietal line can be reduced to greater extent while there is a limitation of the extent to which stature of hybrid can be reduced as the seed cost goes on increasing with increase in plant density of hybrids (Table) .Seed cost does not become a limitation in case of compact varieties even when density is increased to more than 1,00,000/ha Further compact varieties make farmers self sufficiency for their seed needs.

To bring about simultaneous improvement in terms of compactness, with superior boll shape and fibre quality tall compact stature The noval approaches utilizing more parents for hybridization highlighted earlier have been tried in improving compact cotton . Four parents selected for compactness, desirable fibre quality of fibre length above 28mm, fibre strength above 28g/tex tallcompact types with higher boll weight were used in creation of variability and the transgressive segregants

Figure 2 Proportion of alleles from the two parents among segregants in F2



obtained by recombining these four parents have shown a simultaneous improvement in all the targeted traits. These lines are productive and also improved for fibre quality and boll weight.

In developing plant types suitable for machine picking engineers should be parallelly doing sufficient research on modifying cotton picking machines both meant to pick from the entire row and the back pack type of pickers to suite the situation of small farmers. The kind of pickers chosen for use will have a bearing on the plant type suiting the situation of cotton cultivation, Modernization of textile industrial operations constantly raise the benchmark of fibre quality requirements and breeders approaches ,methods and tools of genetic improvements must become more innovative so that the challenge of simultaneous improvement in complex yield ,fibre quality boll traits and stress tolerance traits becomes possible.

Genetic basis of enhancing diversity and improving performance of hybrids: Performance of hybrid depends up on genetic diversity and complementation of parents for loci influencing different important traits between parents. In self pollinated crop like cotton where inbreeding depression is noticed it is possible to draw inference regarding genetic diversity existing between the genotypes. Continuous efforts made on relating hybrid performance in cotton with genetic diversity existing among parents has lead to development of heterotic groups in cotton . In general crosses between robust bushy types and compact types were found to be heterotic because of complementation beteen these groups . In addition the stay green groups of genotypes combined well with high Relative Growth Rate types and also compact types. Several studies were done to identify elite combiners of each group and exploit these heterotic groups for improving combining ability by practicing procedures such as reciprocal selection for combining ability.(Patil and Patil 2007, Patil et al.,. 2011).Initially variability for favourable dominant alleles was created by using two parents in each group . In recent years broad based populations are developed based on four parents in each group.Other studies on

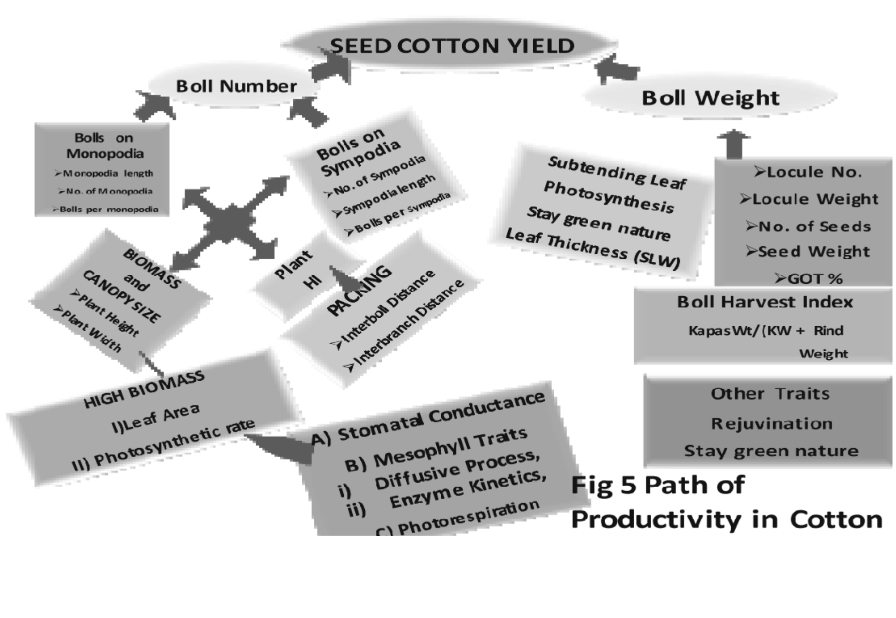


Fig 5 Path of Productivity in Cotton

checking consistency of combining ability over generations was carried out . Though potential crosses were obtained between F3 lines and the opposite groups testers, performance of crosses between the new double cross F3 lines of the opposite groups were found to be more potential. This indicates diversity created between the lines of opposite groups obtained from four parent based crosses. Development of populations of opposite groups based on four elite combiner parents appears to be a promising approach in exploiting heterotic groups.

By acquiring in depth knowledge of Population Genetics and Quantitative Genetics it cotton breeder develops the ability to understand the innovative modifications for each situation in breeding cotton whether it is for development of varieties or hybrids.The innovative approaches followed in creation of useful variability required for varietal development and modifications in approaches of exploiting this variability have shown encouraging results indicating in general that instead of the conventional varietal development approaches there is a need to use innovative modifications in these approaches for deriving superior varieties and hybrids. One of the the objective of this paper was to show how in depth knowledge of the principles of Population Genetics and Quantitative Genetics helps in designing the modifications in procedures/steps of cotton varietal breeding or hybrid development. Knowledge of these two subjects forms the genetic basis of plant breeding There is a need to develop national /international consortia meant to support such innovative research in conventional breeding . The modified procedures of Reciprocal Recurrent selection which is basically defined for cross pollinated crops and it is aimed at increasing genetic diversity between opposite populations.The phenomenon of heterosis is basically having same genetic basis of H_{F1} =”dy^2 and implications of the formula clearly show that by increasing genetic diversity it is possible to increase the magnitude of heterosis .Series of these studies on exploiting heterotic groups show that it is possible to transcend the limits of mating system and utilize the procedure originally described for cross pollinated crops can be used for improving self pollinated crops as well.It is often experience of breeders that innovative ideas of research submitted as eresearch projects generally do not attract the attention of funding agencies and this should go as a message to all such funding agencies as well as Government institutions that such innovative conventional breeding concepts need support on priority.

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INVITED PAPERS

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Employing molecular breeding for genetic improvement of cotton fiber quality : Progress and perspectives

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ABSTRACT : Genetic improvement of fiber quality traits in cotton with enhanced input responsive and adaptation to resource-limited environments through molecular breeding has long been practicedat this Institute. The low rate of polymorphism among *Gossypium* species, in comparison with the other species, has been a major constraint in the development of a high-density genome map. To overcome these constraints, a second approach of genetic mapping is proposed based on many mapping populations for a consensus genetic map in which most of the mapped markers will be common landmarks in all the population that were analyzed. Consensus genetic map has several advantages over individual genetic map for which many crop species have already worked out for the consensus map with the same constraints of polymorphism as that of cotton. Thus, it is hypothesized that there were large numbers of consensus markers that might be sequentially and/or complexly involved in gene regulation that confers superior agronomic traits in cotton. Such efforts have enormous potential in elucidating the molecular mechanism of the investigated traits and more importantly in rapid and precise genetic improvement of cotton through molecular breeding.

Key words : Consensus map, cotton, fiber quality traits, marker assisted selection, SNPs

Cotton (*Gossypium* spp.) is the most preferred textile fibre till date due to its inherent, ecofriendly and comfort characteristics. In addition, it is one of the important cash crops and plays a major role in economic development in many of the Asian and African countries. Globally, India has largest area under cotton (~ 9.0 million ha). Though the area under cotton cultivation is largest, the national cotton production and productivity is low due to several reasons including lack of cultivar that meets requirements of cotton cultivators and millers. Cotton cultivators prefer variety that is suited for their growing environment with less input costs and maximum return. The millers demand for long staple length which is required to spin 40's to 60's. Though significant progress has been made to meet these demands through conventional breeding, still there is a need to genetically improve cotton for fiber quality traits. Hence, development of superior cotton cultivars to meet the requirements of both farmers and textile millers is the core goal of a cotton breeder.

But the complexity of mechanism(s) that involve in fiber growth and development and the difficulty in incorporation of these traits in breeding programs limits the development of superior cotton cultivars through conventional breeding methods. Recent progress in quantitative trait loci (QTL) mapping combined with marker assisted selection (MAS) approach offers a new tool for indirect selection of fiber quality traits. Such a genetic map is necessary not only for the reliable detection, mapping and estimation of gene effects of fiber quality traits, but also for further research on the structure, organization, evolution and function of the cotton genome. QTL mapping of fibre quality traits has been attempted worldwide and most of the studies exploited F_2 populations derived from different parents. However, F_2 population is not preferred in genetic dissection of complex quantitative traits due to several reasons including requirement of large size of F_2 population to ensure recovery of desired recombinants and F_2 progenies can not be used to screen in multiple environments in order to find consistent QTLs across environments. Further, mapping populations from crosses between parental lines that are equally well adapted to target environments should be evaluated. This is because, focusing on the variation within single ecotype might hasten progress toward fiber quality improvement and the locally well-adapted germplasm will increase the efficiency of breeding. So the rational use of genetic resources in breeding programmes to generate a higher level of diversity in the newly released cultivars is the need of the hour.

In our previous study, two different F_2 progenies were developed from SVPR2 / Suvin and P 56-4 / RS 2013 at TNAU and IARI, respectively (Magadum *et al.,* 2012). These parents are diverse for fiber quality and several other agronomically important traits, as well as cotton leaf curl virus resistance (RS 2013) and adaptation to local environments. When these F_2 progenies are forwarded into recombinant inbred lines, they can be considered as valuable resources for continuous and cooperative research at target representative environments and such results will result in identification of consistent QTLs for fiber quality traits in cotton across the environments. Further, use of simple, cost effective and efficient PCR based marker systems such as simple sequence repeats (SSR), Sequence Related Amplified Polymorphism (SRAP) and Randomly Amplified Polymorphic DNA (RAPD) in construction of genetic map may further enhance the efficiency of identification of stable QTLs for fiber quality traits under three different environments (Boopathi, 2013). Upon identification of markers linked to consistent QTLs associated with fiber quality traits, MAS will be efficiently executed for genetic improvement of cotton for fiber quality traits.

Plant materials : P56-4 showed mean fibre strength of 28.1 g/tex during 2003-2004. Its mean fibre strength was observed to be of 27.8 g/tex (Range 26.7 g/rex to 29.4 g/tex) during the period from 2003 to 2007. During the same period it showed mean 2.5 per cent span length of 28.4 mm, micronaire value 3.9, uniformity 53.5 per cent and fibre elongation 6.2 per cent. P 56-4 was thus identified for high fibre strength in the superior long category. Besides these fibre quality traits, P 56-4 was susceptible to CLCuV. RS 2013 released from Sriganganagar has low fiber strength in medium staple category. It is resistant to CLCuV. Both P 56-4 and RS 2013 were evaluated for fiber quality traits at Delhi, Nagpur and Dharwad. The mean fibre strength of P 56-4 was found to be 27.7 g/tex against 22.1 g/tex of RS 2013 over 3 locations. Likewise P 56-4 showed mean 2.5 per cent span length of 28.7 mm, micronaire 3.8, elongation 6.3 per cent against 25.4 mm length, 4.4 micronaire, and 6.1 per cent elongation in RS 2013. The two varieties were also contrasting for boll size and resistance to CLCuV as RS 2013 is resistant to CLCuV and has small bolls.

Based on above considerations P 56-4 and RS 2013 were selected to develop RILs that are segregating for fibre strength. Two hundred and ninety nine single plants from F2 population of the cross P 56-4 and RS 2013 were phenotyped for fibre quality traits. These were advanced to F3 and F4 generations as RILs through single seed descent method and were evaluated for fibre quality traits, respectively during 2007-08 and 2008-09. Among 299 plants in F2, fibre strength was ranged from 18.3 g/tex to 33.1 g/tex with mean of 26.6 g/tex. Fibre strength was ranged from 18.8 g/tex to 27.9 g/tex in F3 with mean of 23.1 g/tex and 20.0 g/tex to 30.7 g/ tex with of 25.1 g/tex in F4. Likewise the fibre length was ranged from 22.7 mm to 30.6 mm in F2; 22.6 to 30.6 mm in F3 and 23.5 to 31.9 in F4.

Similarly, contrasting genotypes for fiber quality traits were also identifiedat TNAU, Coimbatore. SVPR2 is a cotton cultivar released from CRS, TNAU, Srivilliputtur for rainfed tract of southern Tamil Nadu and widely cultivated by the farmers and highly preferred by the millers. It has good tolerance to water stress that is prevailing during the summer cultivation and moderately resistance to pest and diseases. The mean fibre strength of SVPR2 was found to be 16.4 g/tex with a mean 2.5 per cent span length of 25.9 mm and micronaire of 4.7.

G. barbadense var. Suvin is the popularly cultivated cotton cultivar in Tamil Nadu for its superior fiber quality traits. It is well adapted to rice – rice - cotton cropping pattern prevailing in Kavery Delta region. It has 2.5 per cent span length of 38.1 mm and micronaire of 3.3 with 27 g/tex fiber strength.

Hence, it was proposed that development of mapping population using SVPR2 and Suvinwill be segregating for 2.5 per cent span length besides micronaire and fiber strength. A total of 253 F2 progenies were developed by crossing SVPR2 and Suvin and these progenies are being now forwarded to F7 using single seed descent method for the development of recombinant inbred lines. Preliminary analysis of F2 progenies for the fiber quality traits during 2008 have shown that the 2.5 per cent span length was ranged from 25.0 mm to 39.6 mm with a mean of 31.3 mm. The fibre strength was ranged from 15.6 g/tex to 32.4 g/tex with mean of 25.4 g/tex and micronaire was ranged from 3.0 to 5.6 with a mean of 3.9.

Identification of QTLs linked to fiber quality traits will hasten the breeding process through MAS. However, the efficiency MAS will be increased when the QTLs are found to be consistent across the environments and genetic backgrounds. Analysis of F2 populations will not suit for this purpose and hence it is needed to develop some kind of alternative immortal populations such as recombinant inbred lines (RILs). Therefore, in order to identify the stable

QTLs for fiber quality traits across the genetic backgrounds and environments, two different RILs were developed and used in this study.

RESULTS AND DISCUSSION

The individual RILs of the investigated Cotton plants were grown and genomic DNA from leaf of 192 RILs were isolated.Isolated genomic DNA was subjected to quality check (QC) before proceeding for SNP genotyping. All the 192 samples passed the QC analysis, with 260:280 ratios ranging from 1.8-2.0. None of the DNA samples got failed and therefore all the 191 samples were included for SNP genotyping analysis.

After the completion of SNP-typing, genotyping data was filtered and screened to search for the polymorphic parental markers. A total of 2,457polymorphic markers were found and included in the genetic map analysis. However, a total of 46,552 monomorphic markers were excluded in this analysis.

Further, any marker with null parental information was searched and excluded from the analysis. A total of 142 markers from P1 and 172 from P2 (a total of 314) with null data were excluded from the analysis.

Markers with parental heterozygosity were also excluded further. A total of 349 markers from P1 and 484 P2 (a total of 833) markers with heterozygous genotype in any of the parents was removed from the analysis.

After the screening of raw data, a total of 2,457 selected markers were used for the genetic map construction. Genetic map was constructed with LOD 3. Markers with more than 20 per cent of missing genotyping data were automatically removed by the software and displayed the genetic map of tetraploid population spanning length 8331.16cM with an average inter marker distance 5.39cM.

Thus, the progress in linkage map construction offer new avenues to identify QTL hotspots for fiber quality and development of molecular tag for fiber quality in cotton MAS program.

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Speed Breeding in cotton for increasing production in the next decade

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ABSTRACT : Speed breeding is a crop breeding technique originally developed by NASA in the eighties to help grow crops in space and can hasten the process of developing new crop varieties. Over the next 30 years, the global human population is expected to grow by 25 per cent and reach 10 billion. Conventional breeding approaches have so far produced nutritious crops with high yields that can be harvested mechanically to meet the food needs of the growing population. But the current pace of yield increase for major crops, including wheat, rice and maize, is insufficient to meet future demand. Breeders and plant scientists are under pressure to improve existing crops and develop new crops that are higher yielding, more nutritious, pest- and disease-resistant and climate-smart. Unlike when the first grain crops were domesticated 12,000 years ago, plant breeders today have a plethora of innovative technologies to apply in their quest for crop line improvements. For example, the development of automated high throughput phenotyping systems has enabled evaluation of larger populations, which increases selection intensity and improves selection accuracy. The advent of second- and third generation sequencing platforms means that breeders can afford to use DNA markers to assist selections and has facilitated gene discovery, trait dissection and predictive breeding technology. A key limiting factor for plant breeding, the long generation times of crops, which typically allow only one or two generations per year, has been alleviated by 'speed breeding' protocols that use extended photoperiods and controlled temperatures to reduce the generation times by more than half. In practice, introgressing diversity from very distant exotic germplasm pools into elite varieties is often not trivial, due to poor performance of exotic lines in target environments for modern agriculture caused by linkage drag, novel tools like speed breeding can help accelerate this process at extremely high rates. Genetic resources such as landraces are promising for future production demands because many are already adapted to very specific target environments and possess exclusive advantageous characteristics, such as biotic and abiotic stress resistances. A technology fusion incorporating various modern breeding tools and the development of customized pipelines in genetic improvement programs hold great potential to secure future needs in cotton breeding.

Speed breeding is a crop breeding technique originally developed by NASA in the eighties to help grow crops in space and can hasten the process of developing new crop varieties. Many Indian plant scientists are already showing interest in exploring the idea.

Speed breeding' (SB) shortens the breeding cycle and accelerates crop research through rapid generation advancement. SB can be carried out in numerous ways, one of which involves extending the duration of plants' daily exposure to light, combined with early seed harvest, to cycle quickly from seed to seed, thereby reducing the generation times for some long-day or day-neutral crops.

The technique, which uses artificial light and temperature conditions to speed up the crossing and inbreeding of varieties. Lee Hickey, an Australian plant scientist working with University of Queensland, developed Australia's first high-protein milling wheat variety. Hickey is already working in collaboration with the Hyderabad-based International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). They are trying to adapt the speed breeding approach to crops like pigeonpea, millets, sorghum and groundnut. which are important for food and nutrition security in many countries in Africa and Asia.

To improve the productivity and stability of crops, there is pressure to fast-track research and increase the rate of variety development. The generation time of most plant species represents a bottleneck in applied research programs and breeding, creating the need for technologies that accelerate plant development and generation turnover. An approach was reported by Hickey *et al.,* 2017 for SB that involves extending the photoperiod using supplementary lighting and temperature control, enabling rapid generation advancement in glasshouses with sodium vapor lamps or growth chambers fitted with a mixture of metal halide and light-emitting diode (LED) lighting. By adopting a 22-h photoperiod and a controlled temperature regime, generation times were substantially reduced for spring bread wheat, barley, chickpea, pea, canola, the model grass, *B. distachyon*, and the model legume, *Medicago truncatula*, in comparison to those of plants grown in a field or a glasshouse with no supplementary light. Under the rapid growth conditions, plant development was normal, plants could be easily crossed (wheat and barley), and seed germination rates were high. It was demonstrated that SB can be used to accelerate gene transformation pipelines and that adult plant phenotyping for traits such as flowering time, plant height and disease resistance in wheat; leaf sheath glaucousness in barley; and pod shattering in canola could be performed under SB conditions.

Over the next 30 years, the global human population is expected to grow by 25 per cent and reach 10 billion. Conventional breeding approaches have so far produced nutritious crops with high yields that can be harvested mechanically to meet the food needs of the growing population. But the current pace of yield increase for major crops, including wheat (*Triticum aestivum*), rice (*Oryza sativa*) and maize (*Zea mays*), is insufficient to meet future demand. Breeders and plant scientists are under pressure to improve existing crops and develop new crops that are higher yielding, more nutritious, pest- and disease-resistant and climate-smart. Unlike when the first grain crops were domesticated 12,000 years ago, plant breeders today have a plethora of innovative technologies to apply in their quest for crop line improvements. For example, the development of automated high throughput phenotyping systems has enabled evaluation of larger populations, which increases selection intensity and improves selection accuracy. The advent of second- and third generation sequencing platforms means that breeders can afford to use DNA markers to assist selections and has facilitated gene discovery, trait dissection and predictive breeding technology. A key limiting factor for plant breeding, the long generation times of crops, which typically allow only one or two generations per year, has been alleviated by 'speed breeding' protocols that use extended photoperiods and controlled temperatures to reduce the generation times of food crops like spring wheat, barley, chickpea and canola by more than half. Combining such state-of-the-art technologies with speed breeding will help to meet the challenge of feeding the increasing population.

Evolution of speed breeding : Around 150 years ago, botanists first showed that plants can grow n under artificial light using carbon arc lamps. Shortly after, the effects of continuous light on plant growth were evaluated. Arthur and colleagues9 reported that flowering was faster under constant light for the majority of almost 100 plant species, including vegetables, grains, weed species, herbs and garden ornamentals. In the mid-1980s, NASA partnered with Utah State University to explore the possibility of growing rapid cycling wheat under constant light on space stations. This joint effort resulted in the development of 'USU-Apogee', a dwarf wheat line bred for rapid cycling10. Meanwhile, Russian scientists proposed testing 'space mirrors' in 1993 to turn night into day and theoretically improve agricultural productivity on Earth. In 1990, the effects of light-emitting diodes (LEDs) on plant growth were evaluated at the University of Wisconsin, and continuous improvements in LED technology have substantially reduced the cost of indoor plant propagation systems that increase crop productivity. Inspired by NASA's work, researchers at the University of Queensland coined the term 'speed breeding' in 2003 for a set of improved methods to hasten wheat breeding. Speed breeding protocols for multiple crops are now available. Unlike doubled haploid technology, in which haploid embryos are produced and chromosomes are doubled to yield completely homozygous lines, speed breeding is suitable for diverse germplasm and does not require specialized labs for in vitro culturing. The technique uses optimal light quality, light intensity, day length and temperature control to accelerate photosynthesis and flowering, coupled with early seed harvest to shorten the generation time. Specialized protocols are available for species that require specific environmental cues to induce flowering, such as vernalization or short days. When these techniques are applied to small grain cereals that can be grown at high densities—for example, 1,000 plants/m2—the space and cost associated with developing large numbers of inbred lines can be reduced. The combination of 'seed chipping' technology and barcoding for single plant tracking can facilitate high-throughput marker-assisted selection. To accelerate progress in plant research, activities such as crossing, development of mapping populations and adult plant phenotyping for particular traits can be performed in the speed breeding system. Furthermore, speed breeding can accelerate backcrossing and pyramiding of traits, as well as transgenic pipelines. Careful planning can be used to create a pipeline of DNA marker testing, speed breeding and field evaluation. The first spring wheat variety developed using speed breeding, 'DS Faraday', was released in 2017 in Australia. In this case, speed breeding was used accelerate the introgression of genes for grain dormancy that inhibit germination at crop maturity to produce a high-protein milling wheat with improved tolerance to preharvest sprouting. For researchers who do not have access to large facilities, small, low-cost speed breeding units can be set up. Speed breeding could also accelerate the discovery and use of allelic diversity in landraces and in wild relatives of crops. For example, screening of the Vavilov wheat collection for resistance to leaf rust using speed breeding, together with DNA markers linked to known genes, led to the discovery of new sources of resistance.

What is the need for speed breeding? : New technology and advances in science offer new opportunities to further improve the efficiency of agriculture while reducing its environmental footprint, as well as enrich human diets with more nutritious foods. Since the Green Revolution, steady increases in crop productivity have occurred; however, there is concern that yield improvement is beginning to plateau. The current rate of annual yield improvement for major crops ranges between 0.8 and 1.2 per cent, which must be doubled in order to meet the highly increased future demand for plant-based products. Without new approaches that help boost productivity of staple crops through genetic improvement, global food security will be severely compromised in the next two to three decades, given the current global consumer behaviour. There are two main avenues by which crop productivity on farms can be improved: i) through the deployment of genetically superior crop varieties, or ii) via the adoption of better management practices. Ideally, both are addressed in parallel to provide a step-change in productivity, similar to what was achieved during the Green Revolution . One of the major bottlenecks of plant breeding is the time it takes to develop an improved crop variety. Traditionally, it can take one or two decades because of the many steps of crossing, selection and testing required. Therefore, plant breeders and researchers around the world are developing new technologies and approaches to help speed up the efficiency of crop breeding. On farms, the adoption of poor or suboptimal management practices results in a yield 'gap', where the potential of crop yields are not realised. This gap exists even in developed countries, but is often largest in developing countries where agronomy advice, are not readily available.

Mode of reproduction determines the breeding strategy : The main principle ways of sexual propagation relevant to most crop species are outcrossing and inbreeding . Outcrossing species sexually reproduce through hybridization of gametes from two different plants, whereas for inbreeding species both gametes originate from the same plant. Many important cereal crops, such as wheat and barley, are inbred species that produce hermaphrodite flowers. These flowers have biological mechanisms that minimise outcrossing. Classical breeding strategies that have been widely used for these crops are referred to as 'pedigree breeding' approaches, typically resulting in fully homozygous line varieties. Here, plant breeders make crosses by manually removing anthers from the 'female' plant (known as emasculation) and then apply pollen from a different 'male' plant. In this way, directed crosses can be made even for inbreeding species. Depending on the size of the breeding program the total number of directed crosses can range between less than 100 to a few thousand. The offspring segregate and breeders select the best plants during multiple rounds of recurrent inbreeding and field testing. A high level of homozygosity is critical to ensure that the variety that is grown by farmers does not segregate further, potentially exposing recessive genetic variants with detrimental effects on agronomically important traits.

While in outcrossing species, breeders aim to improve a plant population from which the best individuals are recurrently selected and intercrossed during the breeding program, making it conceptually different from line breeding for inbreds, which results in one single, improved genetically homozygous line. The rate of success of population breeding programs depends on whether the target traits are expressed before or after flowering, determining how efficiently unfavourable individuals can be removed to ensure that they are not passing on genetic material to the next generation. One of the most popular strategies for outcrossing crop species is hybrid breeding. Here, two genetically distant inbred lines are crossed to generate fully uniform F1 hybrids that show a significantly higher performance than both parents. This approach takes advantage of a phenomenon called heterosis (or hybrid vigour) and while different theories have been developed, its biological basis remains elusive. In maize, spectacular yield increases have been realised since the implementation of hybrid breeding in the early twentieth century. In rice there are hybrids that produce up to 30% more yield than common inbred lines.

New technologies can speed up crop improvement : New or different approaches are needed to accelerate the crop breeding process. The rate of improvement of genetic yield potential has to be increased beyond the rates currently achieved in ongoing breeding programs to protect global food security in times of rapid population growth and climate change. Over the past decades, numerous technologies have emerged that can accelerate plant breeding, such as genomic selection. In addition to genomics approaches described above, other new methodologies such as gene editing technology are fast-evolving and protocols have been refined for most major crop species. In CRISPR gene editing systems, guide RNA directs the Cas9 enzyme to the target DNA site and cuts the DNA. This can be used to activate or deactivate alleles of a target gene to enhance plant performance, *e.g.* through improving disease resistance or drought tolerance. Despite the promise of gene editing and strong support from the scientific literature regarding safety and sustainability, many countries have employed strict legal frameworks as a consequence of controversial discussions and a rejection of genetically modified food. On the other hand, a very widely used and accepted breeding method is mutation breeding, which uses chemicals or radiation to induce random mutations throughout the genome instead of genetically engineered (targeted) mutation. In fact, spontaneous mutations in the plant genome occur naturally. This is why the majority of the plant science community argue that mutations induced using genome editing where no foreign DNA is introduced should be considered a non-GM tool. Alternatively, 'speed breeding' developed by Dr. Lee Hickey and colleagues provides a non-GM route to rapidly introduce trait variation.

Exploiting genetic resources using SB : The main advantage of Genomic Selection (GS) is that it can be applied to select genotypes in earlier stages of the breeding program, thereby rapidly shortening the breeding cycle and increasing the rate of early genetic gain. This explains the strong difference in yield increases in the GS breeding schemes compared to conventional selection, as short-term selection gains are likely accompanied by fixations and losses of favorable alleles, a decreased genetic variance, and an eventual selection plateau The fourth breeding scheme replenishes genetic diversity through prebreeding, that the trend lines of GS-based approaches converged with phenotypic selection in the long-term perspective. It has already been recognized by other studies that the global production trends in all major crops indicate a yield plateau and that this is most likely caused by an erosion of genetic diversity through the course of intensive selective breeding and germplasm exchange between commercial breeding programs. An interesting hypothesis in this context based on our simulation study is that existing genetic variation in spring wheat could potentially further be exploited to generate considerable yield increases for the next three to four decades until yearly increases reach stagnation, most likely accompanied by a severe loss of favorable alleles. This would also explain the almost identical trends for both speed breeding schemes in the first decades

There are long-term value of prebreeding activities and harnessing genetic diversity by using ancient species or exotic germplasm, such as landraces to sustain a constant increase yields. at sufficient rates. In order to maintain this highly valuable genetic diversity, there are around many gene banks worldwide. The genomic analysis and exploitation of these ancient species is assumed to be a key strategy to achieve further genetic gain in modern cultivars and to reinstate variation of genetic bottlenecks. The rapid development of modern sequencing tools that allow large-scale, high-resolution population characterization at constantly decreasing costs has revolutionized genomics-based crop research during the past two decades and represents an effective means to incorporate and harness genetic resources. In practice, introgressing diversity from very distant exotic germplasm pools into elite varieties is often not trivial, due to poor performance of exotic lines in target environments for modern agriculture caused by linkage drag, novel tools like speed breeding can help accelerate this process at extremely high rates. Genetic resources such as landraces are promising for future production demands because many are already adapted to very specific target environments and possess exclusive advantageous characteristics, such as biotic and abiotic stress resistances.

Future opportunities and challenges : While speed breeding offers a clear advantage in terms of generation time, there is scope for optimizing Speed genomic selection breeding protocols. To further accelerate breeding progress, crossing and growing of F1 plants may also be performed in the speed breeding system rather than in the field. Marker-based selection could be performed at an earlier generation when lines are less homozygous, such as the F4 generation (93.75% inbred), which could dramatically reduce the length of the breeding cycle. In order to most effectively incorporate Rapid Generation Advancement, it is likely the breeding program will have to be re-designed and undergo considerable changes in terms of operations throughout the year. Another aspect is the opportunity to perform phenotypic selection in the speed breeding system. Selection for highly heritable traits, like plant height and disease resistance, could be applied to segregating populations (*i.e.,* F2 and F3) grown in the speed breeding system to effectively enrich resulting inbred lines with desirable alleles, thereby further accelerating genetic gain. Genomic Selection applied to selection candidates already screened for key traits could be a cost-effective way to reduce the number of selection candidates to be genotyped or achieve greater gains. However, the ongoing costs associated with maintaining extended photoperiods and temperatures must be considered from a budget perspective. This is accompanied by relatively high genotyping costs, and while they are decreasing rapidly, the current cost places financial limitations to large-scale high-throughput genome profiling of early generations in the breeding cycle. The higher genetic gains obtained using speed breeding and marker-based selection must be more significant than the costs associated with the integration of the tools. Nevertheless, LED light systems can reduce heat load compared to high-pressure sodium vapor lamps, and thus can reduce the electricity costs for cooling the growth environment. An integration of speed breeding and Genomic Selection would also require elaborate data infrastructures, including data storage, management, and sharing, to efficiently exploit and harness the increasing amount of generated data.

Genome editing, such as the clustered regularly interspaced short palindromic repeats (CRISPR)-associated protein 9 (CRISPR/Cas9) system, presents an exciting opportunity for highly targeted mutagenesis in crop improvement. Large-scale editing of vast numbers of targets across the genome is currently technologically challenging, especially for quantitative traits like yield or drought tolerance. It relies on the initial identification of relevant genes and gene networks to define genomic targets, which is time-consuming and ongoing, but still has the potential to transform plant breeding. Large scale genomic analyses of selection candidates in a breeding program could potentially identify loci with consistently negative effects on traits of interest, representing an ideal target for genome editing approaches to "reverse" these alleles and eventually reinstate the genetic value of specific genotypes in the crossing cycle. The realization of the efficient and profitable incorporation of novel genetic diversity requires well thought out, tailored pre-breeding schemes that address various relevant characteristics for yield increase and stability. A technology fusion incorporating various modern breeding tools and the development of customized pipelines in genetic improvement programs hold great potential to secure future needs in cotton also.

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Performance of GEAC approved *Bt* cotton hybrids in Haryana

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ABSTRACT : A total of 100 promising *Bt* cotton hybrids approved by GEAC for cultivation in north zone were evaluated along with *Bt* check hybrid for seed cotton yield, plant height, boll weight, monopods /plant, bolls /plant, ginning outturn, seed index and fiber quality traits namely, upper half mean fiber length, uniformity ratio, tenacity and micronaire value. The incidence of sucking pests namely, whitefly, leaf-hopper and thrips were recorded at three stages (60, 90 and 120 days after sowing). The observations were also recorded on incidence of bollworms on boll and locule basis at the harvest. Seed cotton yield ranged from 2346 to 5340 kg/ha. Higher yielding hybrids with tolerance /resistance to pests were identified and recommended to the farmers. Many of the *Bt* cotton hybrids were very poor in seed cotton yield. Therefore screening and evaluation of approved *Bt* cotton hybrids is essential for their identification and recommendation to the farmers for increasing the productivity and production of cotton in our country. Sufficient genetic variability exits for different traits. Characteristics of cotton plant type were described based the performance of best genotypes.

Key words: *Bt* cotton hybrids, evaluation, screening, sucking pests

Cotton is also called as white gold and is the most important commercial crop in Haryana which is primarily grown as a fibre crop. It is harvested as 'seed cotton' which is then 'ginned' to separate the seed and lint. The long 'lint' fibres are further processed by spinning to produce yarn. Its fiber is soft and fluffy and hence most widely used for clothing, towels and other household products. Short fibers present on cotton seed after ginning known as 'linters' and they are used in the mattresses, furniture upholstery and mops.

India is famous for cotton textile since ancient times. Gulati and Turner (1929) had critically analyzed the fiber's properties of cotton namely fiber length, weight per unit length, fiber strength and fiber fineness. *G. arboreum* retained its supremacy in the production of cotton goods and muslins cloth manufactured right up to the eighteenth century.

Cotton is grown in tropical and sub-tropical regions of more than 80 countries world over. The major producers of cotton are India, China, USA, Pakistan, Uzbekistan, Argentina, Australia, Greece, Brazil, Mexico, and Turkey. These countries contribute about 85 per cent to the global cotton production. India has the largest acreage (12.655 million ha) under cotton at global level and has the productivity of 537 kg lint/ha. In India at the time of independence, cotton production was around 23 lakh bales as against the requirement of 44 lakh bales and productivity was 132 kg lint /ha. In the year 2002-03 just prior to *Bt* introduction, the area the under cotton was 76.67 lakh ha with a productivity of 308 kg/ ha. During the year 2018-19, the area under cotton was 122.38 lakh ha and productivity 501 kg/ha (Cotton Advisory Board, 2019).

In India, cotton crop is grown in three different zones *i.e.,* north zone, central zone and south zone. north zone comprised of states namely, Punjab, Haryana, Western U.P. and Sriganganagar & Hanumangarh districts of Rajasthan. Out of 51 species of genus *Gossypium*, only two species namely, *Gossypium hirsutum* and *G. arboreum* are cultivated in north zone. High susceptibility of *G. barbadense* to diseases and very long duration of *G. herbaceum* restricts their cultivation in this zone.

Since last many years, the area under *G. hirsutum* has been increasing continuously particularly after introduction of *Bt* cotton hybrids in the year 2005 and at present more than 95per cent of total cotton area is under *Bt* cotton hybrids. During the *kharif* seasons of the years 2013, 2014 and 2015 the heavy incidence of whitefly coupled with cotton leaf curl virus have resulted drastic reduction to cotton productivity in Haryana *i.e.,* 792 kg lint/ha (2011) to 275 kg lint/ha (2015) and cotton growers lost interest in American cotton and as a result cultivated area under cotton crop reduced by more than one lakh ha in the year 2016.Number of measures had been taken by the Universality Scientists in collaboration with state department of Agriculture and Cooperation, Haryana to minimize the losses in cotton yield particularly due to whitefly incidence. These efforts resulted in farmer's faith in cotton cultivation and regain the area under cotton crop. The prominent position of cotton in Haryana has been earned through the development of improved varieties and better crop production and protection technologies.

Cotton crop suffers heavy losses (about 58per cent) in seed cotton yield mainly due to insects in north India. 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 18.5per cent and bollworm contribution is 30.3per cent. Earlier, the bollworm complex *i.e.,* pink boll-worms, spotted bollworms and American bollworms resulted in heavy losses to Cotton crop and the crop could not be protected against these pests in spite of 8-10 sprays of insecticides. 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 I Ac), after that Bollgard II (Mon 15985-Cry I Ac and Cry II Ab) was released for cultivation in 2006, JK Agri genetics developed "Event I" and Nath Seeds GFM event (fusion gene-cry I Ac/ cry I Ab). Since introduction of *Bt* cotton, more than 1000 *Bt* cotton hybrids have been approved for cultivation based on these four events.

Bt cotton has made a substantial contribution in reduction in applications of insecticidal sprays for control of key pests such as American bollworm, pink bollworm, spotted bollworm and tobacco caterpillar. Traditionally, cotton consumed more insecticides than any other crop equivalent to 46per cent of the total insecticide market for all crops in India (Kranthi, 2012). Over the years, the market share for cotton insecticides as a percentage of total insecticides declined steeply from 46per cent in 2001, to 26per cent in 2006 and to 20per cent in 2011. Notably, there has been a very steep decline in insecticide usages particularly on *Helicoverpa armigera* from 71per cent in 2001 to 3per cent in 2011. At the macro-level, the percentage of cotton insecticides to the total pesticides market in India registered a steep decline from 33per cent in 2001 to 11per cent in 2011 at a time when total pesticides market in the country increased significantly during the same period (CIBRC, 2012). This resulted in increase in area under cotton cultivation from 76.67 lakh ha to 116 lakh ha in the year 2014-2015 with almost 95per cent area under *Bt* cotton hybrids (ISAAA, 2014) leading to increase in the production & productivity of the country. But this gain disappeared in few years resulting in some new problems like sudden wilting of plants, increased damage of sucking pests particularly whitefly, threat of minor pests of cotton like mealy bug, mirid bug, aphids and thrips to emerge into major pests, lower down the efficacy of *Bt* gene and appearance of pink bollworm particularly in Gujarat and other parts of the country. Moreover, all the *Bt* cotton hybrids recommended by GEAC are not essentially good seed cotton yielder, under such situation it is essential to evaluate their performance for seed cotton yield and fibre quality parameter so that *Bt* cotton hybrids with proven yield advantage, adaptability and proven fibre quality be encouraged to make Indian cotton cost competitive, quality worthy and comparable with the international cotton. With this objective GEAC approved 100 *Bt* cotton hybrids for north zone were evaluated to meet out the objectives.

MATERIALS AND METHODS

The experimental material consists of hundred *Bt* cotton hybrids along with checks were sown in two replications having a plot size of 4 rows of 6.0 m length each with a spacing of 67.5 cm between row to row and plants were kept 60 cm apart. The sowing of this experiment was done on 02.05.2018 in Cotton Research Area of Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The crop was raised as per the recommended package and practice of university. Two sprays of recommended insecticides were given for managing the sucking pests' incidence as the population of crossed economic threshold level. The data were recorded for characters namely seed cotton yield (kg/ha), boll/plant, boll weight (g), monopods/plant, plant height (cm), ginning outturn (%) and seed index(g). Among the fiber quality parameters observations were recorded for UHML (mm), uniformity ratio, fiber strength and fiber fineness (micronaire value). The data on the incidence of whitefly, leafhopper and thrips were recorded at 60, 90 and 120 days after sowing. Besides, the data of bollworm incidence were also recorded on green boll basis (destructive sampling) at 120 days after sowing and on boll and locule basis at harvest.

RESULTS AND DISCUSSION

The incidence of sucking pests particularly whitefly was very less during *kharif,* 2018 and it remained below the economic thresh-hold level almost during the entire crop season. Distribution of rainfall was excellent for cotton crop almost during the whole crop season. The season was favorable for cotton crop and good seed cotton yield were obtained without any serious problem of insect-pest and diseases. Wide range of variability was observed for different morphological traits (Table 1).

Plant height (cm) : The role of plant height in cotton cannot be specified for all conditions as it may vary with situations. Under high density planting system the sympodial variety with height of about 130 cm will be more desirable for machine picking. For hybrids and poorly managed conditions tall and monopodial plants will be more suitable. In case of hybrids seed production is more costly hence less seed rate with spreading plant type will meet this purpose and similarly in poorly managed soils, plants will have to face more adversity during its life cycle, therefore monopodial type plants will compensate less plant stand. In the present study, plant height ranged from 185cm (6165-2) to 257 cm (Ankur 3224) with a mean value of 220 cm. Significant differences were observed for plant height among the *Bt* hybrids (Table 1).

Number of bolls per plant : This trait was observed to be the most important for seed cotton yield. Wide range was observed 26.4 (JKCH-1050) to 55.7 (311-2) for this trait among the *Bt* cotton hybrids with mean value of 39.8. Forty three *Bt* hybrids yielded significantly superior to best check RCH-773 for boll/plant and three hybrids namely, JKCH 8935, JKCH 1050 and ACH133-2 was significantly inferior to best check. This indicates that most of the *Bt* hybrids were *at par* in bolls/plant to the varieties (Table 1). This character besides genotypic differences also influenced greatly by environmental factors like rainfall, humidity, drought, wind direction, spacing, sowing time, nutrient status of soil and damage by biotic factors.

Boll weight (g) : Boll weight in cotton is a second major yield contributing character after boll/plant. Larger boll size is advantageous as they had easy to pick with less trash content. Presently cotton growing farmers can sacrifice the some seed cotton yield advantage for big boll size variety/hybrid because picker charges are more in varieties/hybrids with smaller sized bolls. In general boll size in north zone remains smaller compared to south and central zone because of short development period in this zone. The range for this trait was 3.4 g (JKCH 1947) to 5.5 g (JKCH-1050) was observed the *Bt* cotton hybrids with mean value of 4.4 g. Two *Bt* hybrids *i.e.,* JKCH 8935 and JKCH 1050 yielded significantly superior to best check RCH 773 for boll weight indicated their superiority for this trait in *Bt* hybrids (Table 1).

Ginning outturn (%) : Ginning outturn is a character of economic importance and in general it is inversely proportional to the fibre quality in cotton. Cotton is mainly grown for lint purpose so higher ginning outturn is big advantage. The range for this trait was 29.9 per

Table 1. Performance of GEAC recommended *Bt* cotton hybrids during *kharif* 2018 at Hisar

S. No.	Hybrid	Seed cotton yield (kg/ha)	Boll weight (g)	Bolls/ plant	Plant height (cm)	Mono-pods/ plant	GOT (%)	Seed index (g)	UHML	UI	Tenacity	Mic.
1	ACH177-2	5340	4.4	53.5	242	1.8	38	9	29.5	83	33.6	4.5
2	MRC7365	5278	5.2	41	235	1	39.2	11	31	84	32.2	4
3	311-2	5216	4.5	55.7	231	1.5	33.9	9.8	29.5	83	32.7	4.6
4	PCH9611	5123	4.6	44.4	217	1.6	34	11.3	29.6	83	33.1	4.5
5	NSPL252	5000	4.2	48.1	229	1.5	36.3	10	27.3	82	30.6	4.6
6	SHAKTI9	4969	5.1	43	230	0.8	34.6	9.5	30	83	33.7	4.3
7	JKCH8940	4938	4.6	44.6	206	1.4	35.8	10	28.1	83	32	4.5
8	SWCH4757	4938	4.5	48.8	231	2	36.9	9.5	28.1	83	31.2	4.3
9	RCH650	4784	4.9	39	254	2	36.6	10.5	27.3	82	32.1	4.6
10	JKCH0109	4784	4.9	43.6	215	1.5	36.4	9.5	28	82	32.4	4.6
11	SWCH4748	4753	4.7	41.8	206	1.5	35.7	8	29.4	83	32	4.2
12	6539-2	4722	5	37.2	217	1.8	35.8	9.8	28.1	83	31.7	4.4
13	ABCH244	4722	4.4	50. 5	231	1.6	34.8	9	27.8	82	31.2	4.7
14	RCH569	4722	4.5	47.9	212	1.5	35.1	9.5	29.4	83	28.8	4.8
15	RCH314	4691	4.9	41.4	213	1.7	37.3	10	28.2	83	33	4.1
16	KCH999	4660	4.4	44.5	214	2.2	37.8	9.3	28	83	31.9	4.3
17	NAMCOT617	4660	4.6	42.9	222	1.2	35.9	9.3	27.8	82	31.3	4.5
18	RCH809	4660	4.8	42	227	1.2	36.5	10	27.2	82	31.5	4.5
19	SUPER 511	4630	4.6	45	196	1.2	34.4	9.8	30.2	84	33	4.7
20	RCH653	4599	4.7	40.2	213	1.3	33.8	10	28.8	83	32.9	4.2
21	841-2	4599	4.4	45	233	2.2	36.5	9	28.6	83	32.9	4.1
22	RCH776	4475	4.9	41.9	235	1.8	36.1	10.3	28.7	83	33.3	4.6
23	RCH791	4475	4.8	40.4	231	1.3	37.3	9.3	28	83	32.1	4.5
24	SUPER544	4475	4.5	42.3	233	1.8	34.8	9.3	27.3	82	30.8	4.3
25	2510-2	4444	4.7	40.4	218	1	38.7	10.3	30.2	84	32.4	4.7
26	2113-2	4444	4.5	41.9	198	1.6	37.1	10.3	29.8	83	32.8	4.8
27	ACH155-2	4414	4.2	43.2	219	1.5	36	8.8	29.4	83	30.3	4
28	SWCH4755	4383	4.8	40.1	209	1	36.7	10	30.3	84	31.7	4.4
29	ABCH4899	4352	4.1	47	235	1.5	35.2	8.3	27.7	82	28.4	4.9
30	RCH 773(C)	4352	4.8	36	202	1.5	35.2	10	30.5	84	33.6	4.7
31	ANKUR3244	4321	4.8	39.7	225	2	35.5	10	28.4	83	33.9	4.5
32	KDCHH516	4259	4.5	39.3	242	1.2	36.5	9.5	28.6	83	31.8	4.5
33	MRC7041	4259	4.2	49.7	213	2.2	37.6	9.3	28.3	83	31.4	4.5
34	MH5302	4259	4.7	32.7	224	2.2	36.4	9	27.2	82	29.7	4.4
35	NSPL2223	4228	4.5	40.5	248	1.2	36.1	9.5	27.7	82	31.5	4.5
36	RCH602	4198	4.5	42.9	210	1.5	34.6	10	30.2	84	33.5	4.1
37	SOLAR77	4198	5.1	34.2	214	2.3	34.1	10	28.6	83	31.6	4.5
38	SOLAR75	4198	3.8	44.6	212	1.8	33.2	8.8	30.1	84	32.2	4.2
39	SWCH4704	4136	5	37.2	227	1.6	36.8	9.8	29	83	32.5	4.4
40	NCS904	4136	4.6	37.4	218	1.3	35.7	10.3	30.2	84	33.9	4.4

contd...

Table 1 contd..

41	ABCH243	4105	4.6	41.4	218	2	36.1	9.8	28.3	83	31.2	4.4
42	JKCH12124	4105	4.3	40.6	224	1.8	33.3	8.3	31	84	31	3.9
43	NCS857	4105	5.2	32.9	214	1	33.7	10.3	27.8	82	31.1	4.3
44	JKCH1947	4105	3.4	48.6	236	2	33.4	9	30.5	84	33.4	4.4
45	SWCH4711	4105	4.6	38	221	1.2	34.7	10.3	26.6	82	30.3	4.4
46	NCS459	4074	4	43.3	221	1.3	38.5	9.3	29.7	83	32.3	4.5
47	VICH308	4074	4.5	37.9	203	2.2	33.1	9	29.7	83	32.2	4.3
48	NCS2223	4043	4	41.8	193	2.3	34	8.8	29.3	83	32.3	4.2
49	NCS9012	4012	4.5	38.2	206	1.6	34	9	27.2	82	30.4	4.2
50	KDCHH641	3981	4.9	36	207	1.2	32.2	10.3	30.4	84	32	4.6
51	NAMCOT641	3951	5.3	36.4	217	1.1	35.9	9.5	30	83	32.4	4.4
52	KSCH207	3951	4	44	208	2	33.8	9	29.7	83	32.8	4.3
53	SOLAR56	3920	4.1	41	224	1.6	39	8.5	31	84	31.8	4.9
54	PCH1414	3889	4	39.7	229	1.3	40.8	7	29.4	83	31.6	4
55	NCEH6	3889	3.8	41.6	241	1.5	37.3	10.3	29.2	83	32.9	4.6
56	ABCH2099	3889	4.7	42.2	216	2.2	35.1	9	28.3	83	31.5	4.2
57	PCH877	3858	4.2	45.2	221	2.6	36.7	9	29.9	83	31.7	4.4
58	SUPER 965	3858	4.9	36.1	223	1.3	36	9.3	27.1	82	30.3	4.3
59	PCH5678	3858	4	41.9	213	1.3	34.8	10	30.9	84	32.6	4
60	ANKUR5642	3858	4.1	41.6	237	2.4	36.5	9.3	29.6	83	33.4	4.4
61	KCH172	3858	3.9	46.7	196	2.5	32.3	9	30.1	84	33.8	4.4
62	SUPER721	3827	4.4	40.2	215	1.7	35	11.5	32.3	84	32.6	4.2
63	SWCH4713	3796	4.4	35.4	203	1	36.7	8	29.9	83	31.5	4.3
64	JKCH8935	3796	5.4	29.8	199	1.5	34.1	10.3	29.2	83	31.2	4.4
65	6488	3781	3.9	42	228	2.4	33	8.8	30.5	84	33.1	4.2
66	NCS9013	3719	4.2	37.8	209	2.3	33	9	30.1	84	32.5	4.1
67	NCS9024	3704	4.3	36.4	216	1.8	36.6	10.3	29.6	83	31.8	4.4
68	NCS858	3704	3.9	43	210	2.3	34.9	9.3	31.6	84	33.2	4.5
69	SUPER 971	3704	4.4	35.4	213	1.7	36.1	9.8	29.9	83	31.8	4.1
70	PRCH333	3642	4.4	41	222	1.8	36.4	7.8	29.2	83	33.6	4.6
71	SWCH4744	3642	4.8	43	221	1.8	36.1	10.5	30.2	84	34.2	4.6
72	PCH225	3642	4.7	37	204	1.5	35.8	8.5	28.6	83	30.6	4.4
73	NCS9002	3611	4.7	35.7	205	1.6	37.9	9.8	29.5	83	34.2	4.5
74	NCS855	3611	5	32.7	231	1.8	34.4	9	28.6	83	30.6	4.8
75	ABCH252	3611	4.6	37.1	213	2	35.3	9.8	31	84	34.4	4.5
76	JKCH TARZAN	3611	4.6	31.6	237	2.1	34.6	9	29.4	83	33.6	4.3
77	SP7114	3611	4	43.7	229	2.5	30.7	10.3	29.1	83	32	5
78	PCH9604	3611	5	31.8	197	2.5	39.2	8	26	82	26.8	5.7
79	ANKURJASSI	3611	4	40.5	201	2.1	34.3	9	30.5	84	34.2	4.4
80	ABCH143	3580	4.8	33.2	233	1.3	38.9	8	27.9	82	29.9	5.2
81	NCS495	3580	3.6	41	212	1.8	34	9.5	30.4	84	34.1	4.3
82	ANKUR3228	3519	4.5	37.3	212	1.2	38.8	9.3	30.6	84	33.6	4.7
83	NAMCOT616	3519	3.7	42.4	231	1.5	34.2	8.3	29.9	84	34.9	4.2
84	PRCH7799	3488	3.8	42	220	1.6	39.3	8	26.8	82	28.2	5.2
85	SOLAR64	3488	3.6	44.8	195	1.8	31.5	9	30.8	84	34.7	4.7

contd...

Table 1 contd...

86	846-2	3364	4.4	34.5	225	2.3	37.4	7.5	29.5	83	33	4.3
87	ANKUR3028	3333	4.2	37.4	219	1.8	39.3	7	29	83	30.8	4.9
88	ACH777-2	3333	4.4	34.2	230	1.7	36.1	8.8	31.4	84	30.6	4.2
89	NBC74	3272	4.7	32.7	241	1.8	35.2	47	30.7	84	33	4.4
90	ABCH1299	3241	4.3	31.4	229	2.3	34.4	9.5	30.1	84	31.8	4.3
91	ABCH192	3210	4.2	38.5	231	2.1	35	8.8	29	83	32	5.4
92	JKCH1050	3133	5.5	26.4	209	1.2	33.8	9.4	29	83	31.8	4.2
93	NCS9011	3086	4	34	239	1.3	34.6	7.5	29.1	83	32	3.9
94	SOLAR65	2994	4.3	31.1	226	1.8	36	9	29	83	33.3	4.3
95	GOLD STAR	2994	3.5	39.7	226	2.3	33.1	9	28	83	31.1	4
96	ACH33-2	2963	4.3	34. 5	239	1.8	34.6	7.8	30.2	84	32.8	3.4
97	6165-2	2963	3.9	37.2	185	1.7	33.9	8.3	32.2	84	33	4.1
98	SO7H878	2747	3.8	32.5	232	1.3	36.1	8.3	30.1	84	33.4	3.8
99	ANKUR3224	2377	3.7	36.2	257	2.7	38.6	7.3	28.6	83	32.5	3.4
100	ACH133-2	2346	4	27.3	243	2.3	36	8.3	29.6	83	32.9	3.9
	C D (p=0.05)	973.7	0.54	5.3	7.7	0.5	0.7	0.4				
	C V (%)	12.2	6.09	8.18	2.30	18.27	1.26	2.73				

cent (PRCH 7799 BGII) to 40 per cent (KDCHH-516 BG II) observed in *Bt* cotton hybrids with mean value of 35per cent and non *Bt* varieties F 2228 and H 1098-I had boll weight of 33 per cent and 36.5 per cent respectively. There is need to identify higher ginning out turn genotypes with high yield and better fibre quality parameters.

Seed cotton yield (kg/ha) : Seed cotton yield is a complex trait because it is a product of plants/unit area, bolls/plant and boll weight. This trait is highly variable as it is highly influenced by environmental factors. The seed cotton yield ranged from 2346 kg/ha (ACH133-2) to 5340 kg/ha (ACH 177-2) with a mean value of 4001 kg/ha and check varieties RCH 773 (4352 kg/ha) and 28 hybrids were at par with check attaining higher yield than it while 55 hybrids were at par with check attaining lower yield than check. Only one *Bt* hybrid *i.e.,* ACH-177-2 yielded significantly superior to best check RCH-773 for seed cotton indicated its superiority for this trait in *Bt* hybrids and fifteen *Bt* hybrids were significantly poor to the Check RCH-773 and rest were at par in seed cotton yield (Table 1). These results indicated that varieties are not poor yielder than many of the *Bt* cotton hybrids. Perusal of results of this experiment showed that only limited *Bt* hybrids had superiority in seed cotton yield. Therefore screening and evaluation of approved *Bt* cotton hybrids is essential for identification and recommendation of superior hybrids to the farmers that certainly will lead to quantum jump in cotton production and productivity.

The mean value for seed cotton yield of 10 superior *Bt* cotton hybrids is 5037 kg/ha which is far above from state average indicated that if suitable *Bt* hybrids after proper screening are chosen there is wide scope to increase the cotton productivity (Table 2). From this table we can also conclude that under normal situation for cotton crop, for ideotype plant should have the plant height of about 180 cm with 45-50 bolls

Table 2: Superior *Bt* cotton hybrids for seed cotton yield and other traits

S. No.	Hybrid	Seed cotton yield (kg/ha)	Boll weight (g)	Bolls/ plant	Plant height (cm)	Mono- pods/ plant	GOT (%)	Seed index (g)	UHML	UI	Tenacity	Mic.
1	ACH177-2	5340	4.4	53.5	242	1.8	38	9	29.5	83	33.6	4.5
2	MRC7365	5278	5.2	41	235	1	39.2	11	31	84	32.2	4
3	311-2	5216	4.5	55.7	231	1.5	33.9	9.8	29.5	83	32.7	4.6
4	PCH9611	5123	4.6	44.4	217	1.6	34	11.3	29.6	83	33.1	4.5
5	NSPL252	5000	4.2	48.1	229	1.5	36.3	10	27.3	82	30.6	4.6
6	SHAKTI9	4969	5.1	43	230	0.8	34.6	9.5	30	83	33.7	4.3
7	JKCH8940	4938	4.6	44.6	206	1.4	35.8	10	28.1	83	32	4.5
8	SWCH4757	4938	4.5	48.8	231	2	36.9	9.5	28.1	83	31.2	4.3
9	RCH650	4784	4.9	39	254	2	36.6	10.5	27.3	82	32.1	4.6
10	JKCH0109	4784	4.9	43.6	215	1.5	36.4	9.5	28	82	32.4	4.6
Mean		5037	4.7	46.2	229	1.5	36.2	10.0	28.8	82.8	32.4	4.5
Overall mean		4001	4.4	39.8	220	1.7	35.7	9.6	29.2	83.1	32.1	4.4

per plant with a boll weight of about 4 to 4.5 g for obtaining good seed cotton yield. Although boll weight is an important seed cotton yield contributing character but its association with boll number per plant is either negative (Pujer *et al.,* 2014) or no association is reported by Reddy *et al.,* 2017 and Patil *et al.,* 2017 in upland cotton. These workers also reported strong association of number of bolls per plant with seed cotton yield and poor with boll weight indicated that more emphasis should be given to increase the boll number per plant.

Number of monopods : The numbers of monopod have a direct effect on seed cotton yield the average monopods/plant range from 0.8 to 2.7. Out of the 100 hybrids twenty four were found significantly superior in the character monopods/plant. Highest monopods/plant was observed in the hybrid Ankur 3224. Only one hybrid *i.e.,* Shakti-9 was significantly inferior.

Ginning outturn (%) : The GOT (%) showed a wide range from 30.7 to 40.8. The lowest GOT percentage was sown by the hybrid SP 7114 and the maximum by PCH 1414. Total 47 hybrids were significantly superior to the national check hybrid RCH 773

Seed index (g) : Seed index is the character which affects the yield as well as quality like vigor. The minimum seed index (7 gm.) was shown by two hybrids namely PCH 1414 and Ankur 3028.

Among fibre quality parameters namely UHML (mm), uniformity ratio, fiber strength and fiber fineness (micronaire value) no much variability was observed among the tested *Bt* cotton hybrids.

Incidence of insect pests : The incidence of sucking insect pests namely, whitefly, leafhopper and thrips are presented in the Table 3. The population of whitefly among the tested hybrid varied from 8.8 to 16.2, 16.6 to 26.3 and 12.5 to 19.4 whiteflies/ 3 leaves at 60,

Table 3. Incidence of sucking pests at different intervals in GEAC approved *Bt* cotton hybrids during *Kharif* 2018 at Hisar

S. No.	Hybrid	Whiteflies/3 leaves				Thrips/3 leaves				Leafhoppers/3 leaves			
		60 DAS	90 DAS	120 DAS	**Mean**	60 DAS	90 DAS	120 DAS	Mean	60 DAS	90 DAS	120 DAS	Mean
1	ACH177-2	13.50	19.30	16.10	**16.30**	29.80	7.90	2.30	**13.33**	3.60	3.70	2.20	**3.17**
2	MRC7365	12.10	20.10	15.70	**15.97**	26.90	8.80	2.30	**12.67**	3.50	4.20	2.50	**3.40**
3	311-2	12.40	18.20	14.10	**14.90**	29.00	7.50	2.20	**12.90**	3.20	3.90	2.40	**3.17**
4	PCH9611	12.10	18.80	16.40	**15.77**	25.90	8.70	2.60	**12.40**	3.40	4.00	2.50	**3.30**
5	NSPL252	12.70	20.50	15.90	**16.37**	31.60	8.50	3.10	**14.40**	3.80	3.90	3.20	**3.63**
6	SHAKTI9	13.40	19.40	15.40	**16.07**	29.00	8.40	2.80	**13.40**	4.50	3.80	3.00	**3.77**
7	JKCH8940	13.40	19.70	17.50	**16.87**	28.90	8.30	2.70	**13.30**	4.40	3.50	3.30	**3.73**
8	SWCH4757	13.20	20.00	18.60	**17.27**	28.80	8.90	3.10	**13.60**	4.20	4.00	3.40	**3.87**
9	RCH650	14.30	21.70	15.40	**17.13**	33.90	10.10	2.90	**15.63**	5.30	5.20	3.60	**4.70**
10	JKCH0109	14.30	21.10	18.80	**18.07**	32.10	9.80	3.10	**15.00**	5.30	3.70	3.30	**4.10**
11	SWCH4748	11.30	19.50	16.70	**15.83**	29.40	8.10	2.60	**13.37**	4.60	3.30	2.90	**3.60**
12	6539-2	14.80	20.10	19.00	**17.97**	34.90	9.60	3.50	**16.00**	5.20	4.10	3.80	**4.37**
13	ABCH244	15.40	20.90	13.70	**16.67**	32.10	9.10	2.60	**14.60**	6.10	3.70	2.90	**4.23**
14	RCH569	14.70	21.20	18.20	**18.03**	32.00	9.90	3.00	**14.97**	5.20	3.60	3.00	**3.93**
15	RCH314	13.10	21.30	17.00	**17.13**	31.90	10.00	2.90	**14.93**	5.10	4.10	3.00	**4.07**
16	KCH999	14.80	21.30	18.50	**18.20**	33.00	8.40	3.00	**14.80**	5.70	4.10	3.40	**4.40**
17	NAMCOT617	16.20	19.80	16.50	**17.50**	37.80	7.30	2.60	**15.90**	4.40	3.60	2.60	**3.53**
18	RCH809	13.00	20.50	15.30	**16.27**	31.20	8.20	2.80	**14.07**	5.40	4.00	2.40	**3.93**
19	SUPER 511	14.90	20.70	17.00	**17.53**	33.00	9.70	2.60	**15.10**	5.30	3.90	2.80	**4.00**
20	RCH653	14.80	19.80	17.50	**17.37**	34.90	8.90	3.00	**15.60**	6.70	3.40	3.00	**4.37**
21	841-2	14.80	21.10	17.80	**17.90**	35.60	11.10	2.90	**16.53**	6.40	4.20	3.80	**4.80**
22	RCH776	15.20	19.70	16.70	**17.20**	34.90	7.70	2.90	**15.17**	6.40	3.60	2.60	**4.20**
23	RCH791	14.90	20.50	17.80	**17.73**	33.50	8.90	2.60	**15.00**	7.40	4.10	2.60	**4.70**
24	SUPER544	15.00	20.00	16.70	**17.23**	37.70	8.30	2.80	**16.27**	7.80	4.00	3.10	**4.97**
25	2510-2	15.80	19.20	17.60	**17.53**	37.90	8.20	2.80	**16.30**	7.30	4.00	3.10	**4.80**
26	2113-2	15.40	20.70	18.70	**18.27**	35.20	9.80	3.10	**16.03**	7.30	4.80	3.40	**5.17**
27	ACH155-2	15.40	20.90	18.20	**18.17**	35.30	9.10	3.10	**15.83**	7.20	3.70	3.50	**4.80**
28	SWCH4755	13.80	21.90	19.40	**18.37**	31.50	8.90	3.60	**14.67**	4.00	4.00	2.80	**3.60**
29	ABCH4899	13.90	20.50	18.90	**17.77**	33.00	8.20	3.30	**14.83**	6.60	5.30	2.70	**4.87**
30	RCH 773	14.30	20.80	17.80	**17.63**	32.90	8.70	2.90	**14.83**	4.80	4.60	2.40	**3.93**
31	ANKUR3244	13.10	18.70	16.40	**16.07**	32.30	7.50	2.80	**14.20**	5.10	3.30	2.80	**3.73**
32	KDCHH516	11.00	21.10	17.10	**16.40**	27.80	10.00	2.90	**13.57**	5.20	4.20	3.00	**4.13**
33	MRC7041	14.40	20.70	16.00	**17.03**	32.50	9.00	2.60	**14.70**	6.00	4.10	2.70	**4.27**
34	MH5302	13.90	20.80	16.40	**17.03**	32.30	8.40	2.50	**14.40**	5.00	3.60	3.10	**3.90**
35	NSPL2223	14.10	19.50	14.30	**15.97**	34.30	8.20	2.40	**14.97**	4.80	3.20	3.20	**3.73**
36	RCH602	14.30	18.50	15.30	**16.03**	32.70	8.10	2.70	**14.50**	4.40	3.70	3.00	**3.70**
37	SOLAR77	12.80	19.20	16.80	**16.27**	31.80	7.90	2.50	**14.07**	4.50	3.80	3.70	**4.00**
38	SOLAR75	12.50	20.10	16.10	**16.23**	27.70	8.10	2.80	**12.87**	4.70	3.60	3.40	**3.90**
39	SWCH4704	14.80	20.80	16.00	**17.20**	34.10	8.90	3.00	**15.33**	5.40	4.30	3.80	**4.50**
40	NCS904	12.80	19.30	17.50	**16.53**	32.30	8.40	3.00	**14.57**	5.10	3.20	4.00	**4.10**
41	ABCH243	12.80	21.30	17.10	**17.07**	31.80	7.80	3.10	**14.23**	5.20	5.00	2.90	**4.37**

contd...

Table 1 contd...

42	JKCH12124	14.90	19.70	16.30	**16.97**	32.40	9.00	2.70	**14.70**	5.20	4.00	2.60	**3.93**
43	NCS857	13.80	21.00	17.40	**17.40**	32.70	8.00	2.90	**14.53**	5.30	3.50	3.00	**3.93**
44	JKCH1947	15.60	23.30	15.50	**18.13**	35.50	8.00	2.70	**15.40**	5.40	4.00	3.00	**4.13**
45	SWCH4711	13.50	20.10	16.50	**16.70**	29.20	8.70	2.90	**13.60**	5.00	3.40	2.80	**3.73**
46	NCS459	15.80	19.90	17.30	**17.67**	36.40	8.80	3.00	**16.07**	4.90	4.50	3.20	**4.20**
47	VICH308	15.00	22.10	17.40	**18.17**	36.10	10.10	3.20	**16.47**	5.10	4.20	3.20	**4.17**
48	NCS2223	13.90	20.50	13.40	**15.93**	35.40	9.10	2.70	**15.73**	5.10	4.00	2.80	**3.97**
49	NCS9012	14.60	19.20	14.70	**16.17**	37.10	8.20	2.70	**16.00**	5.00	3.60	2.80	**3.80**
50	KDCHH641	15.00	21.20	18.30	**18.17**	36.60	9.60	3.50	**16.57**	6.10	3.70	2.90	**4.23**
51	NAMCOT641	15.60	23.00	17.70	**18.77**	34.90	10.60	3.20	**16.23**	4.20	4.20	3.50	**3.97**
52	KSCH207	14.60	22.10	15.10	**17.27**	33.40	9.30	2.80	**15.17**	5.30	3.60	3.20	**4.03**
53	SOLAR56	15.40	21.20	13.80	**16.80**	33.80	8.80	2.60	**15.07**	6.80	3.90	2.80	**4.50**
54	PCH1414	16.00	20.30	14.00	**16.77**	36.80	8.20	2.60	**15.87**	6.90	3.70	3.40	**4.67**
55	NCEH6	14.00	20.10	16.70	**16.93**	31.70	9.10	3.20	**14.67**	4.80	3.70	3.60	**4.03**
56	ABCH2099	14.90	20.80	17.80	**17.83**	35.80	8.30	3.40	**15.83**	5.90	4.10	3.60	**4.53**
57	PCH877	13.60	24.60	16.80	**18.33**	32.00	10.30	3.40	**15.23**	5.80	4.70	3.00	**4.50**
58	SUPER 965	15.10	19.50	16.90	**17.17**	31.70	8.30	3.30	**14.43**	5.20	3.60	4.00	**4.27**
59	PCH5678	14.90	23.00	18.80	**18.90**	33.80	9.20	3.20	**15.40**	6.20	4.10	4.00	**4.77**
60	ANKUR5642	14.50	21.80	16.40	**17.57**	33.50	9.00	2.90	**15.13**	5.70	3.80	3.80	**4.43**
61	KCH172	14.30	21.00	16.80	**17.37**	32.60	8.40	3.10	**14.70**	5.30	4.10	3.50	**4.30**
62	SUPER721	13.80	22.50	16.70	**17.67**	35.00	8.90	3.20	**15.70**	5.00	4.90	3.00	**4.30**
63	SWCH4713	12.80	22.00	15.60	**16.80**	31.40	9.30	3.40	**14.70**	4.90	4.10	3.00	**4.00**
64	JKCH8935	14.90	19.30	15.80	**16.67**	34.50	8.30	3.10	**15.30**	6.50	3.70	3.40	**4.53**
65	6488	13.40	20.00	15.30	**16.23**	31.40	8.00	2.40	**13.93**	5.70	4.10	3.30	**4.37**
66	NCS9013	8.80	20.50	13.60	**14.30**	32.10	8.70	2.20	**14.33**	3.50	4.20	2.70	**3.47**
67	NCS9024	12.40	16.70	14.50	**14.53**	31.00	6.70	2.40	**13.37**	5.40	3.20	3.20	**3.93**
68	NCS858	13.00	16.60	14.70	**14.77**	35.40	7.10	2.60	**15.03**	6.00	3.40	2.60	**4.00**
69	SUPER 971	14.30	19.00	14.00	**15.77**	37.50	7.30	2.40	**15.73**	6.60	3.60	2.30	**4.17**
70	PRCH333	13.00	21.20	13.80	**16.00**	34.10	8.60	2.50	**15.07**	5.90	4.50	3.10	**4.50**
71	SWCH4744	11.90	21.10	15.50	**16.17**	34.60	8.50	2.60	**15.23**	5.20	3.50	3.60	**4.10**
72	PCH225	13.00	20.50	13.60	**15.70**	34.70	7.40	2.10	**14.73**	5.10	3.80	3.10	**4.00**
73	NCS9002	13.60	20.60	16.10	**16.77**	35.90	7.90	2.80	**15.53**	5.40	3.20	3.60	**4.07**
74	NCS855	13.50	20.00	15.00	**16.17**	35.20	8.30	2.50	**15.33**	5.30	3.50	3.40	**4.07**
75	ABCH252	12.40	18.50	14.40	**15.10**	30.50	8.10	2.50	**13.70**	5.60	3.60	3.30	**4.17**
76	JKCH TARZAN	13.10	21.40	15.70	**16.73**	33.70	10.40	2.80	**15.63**	4.90	4.20	3.40	**4.17**
77	SP7114	14.80	18.80	13.50	**15.70**	38.20	8.20	2.30	**16.23**	6.60	3.60	3.10	**4.43**
78	PCH9604	11.10	26.30	12.90	**16.77**	31.50	10.10	2.20	**14.60**	4.20	4.00	2.80	**3.67**
79	ANKURJASSI	13.80	20.50	12.60	**15.63**	31.30	8.70	2.30	**14.10**	5.20	4.20	2.70	**4.03**
80	ABCH143	13.20	19.10	12.50	**14.93**	33.30	8.60	2.30	**14.73**	6.10	4.00	2.80	**4.30**
81	NCS495	13.40	20.30	13.60	**15.77**	31.60	8.30	2.50	**14.13**	6.30	3.50	3.00	**4.27**
82	ANKUR3228	11.90	19.80	12.50	**14.73**	31.10	8.70	2.50	**14.10**	4.60	3.70	2.80	**3.70**
83	NAMCOT616	12.20	22.70	12.90	**15.93**	33.10	9.90	2.60	**15.20**	5.10	3.80	3.00	**3.97**
84	PRCH7799	13.20	19.20	17.40	**16.60**	33.40	8.10	3.20	**14.90**	6.00	3.80	3.60	**4.47**
85	SOLAR64	13.60	18.90	17.00	**16.50**	33.00	8.20	3.00	**14.73**	5.30	3.50	3.60	**4.13**

contd...

Table 1 contd...

86	846-2	11.60	21.90	15.50	**16.33**	32.80	9.50	3.00	**15.10**	6.00	4.30	3.70	**4.67**
87	ANKUR3028	14.70	20.20	14.00	**16.30**	36.50	8.40	2.80	**15.90**	4.50	3.80	3.60	**3.97**
88	ACH777-2	12.60	19.80	15.40	**15.93**	30.20	7.60	2.90	**13.57**	4.50	3.60	3.50	**3.87**
89	NBC74	10.30	20.50	14.90	**15.23**	24.50	9.10	2.90	**12.17**	3.90	3.20	3.60	**3.57**
90	ABCH1299	11.90	20.40	13.70	**15.33**	31.40	7.50	2.90	**13.93**	4.90	4.10	3.40	**4.13**
91	ABCH192	13.10	22.60	15.10	**16.93**	31.80	10.30	3.00	**15.03**	5.20	4.30	3.40	**4.30**
92	JKCH1050	12.70	22.30	15.70	**16.90**	32.20	8.50	3.00	**14.57**	5.30	4.20	3.50	**4.33**
93	NCS9011	13.10	21.00	13.40	**15.83**	33.60	9.00	2.60	**15.07**	5.70	3.80	3.70	**4.40**
94	SOLAR65	12.40	22.50	14.60	**16.50**	30.60	9.70	2.90	**14.40**	4.20	4.20	3.50	**3.97**
95	GOLD STAR	12.70	21.10	14.60	**16.13**	31.10	7.70	3.20	**14.00**	5.10	3.90	3.60	**4.20**
96	ACH33-2	12.70	19.40	13.90	**15.33**	31.00	7.70	2.80	**13.83**	4.50	3.20	3.40	**3.70**
97	6165-2	12.70	20.20	12.80	**15.23**	30.90	9.20	2.50	**14.20**	3.80	3.30	3.20	**3.43**
98	SO7H878	9.10	19.60	15.10	**14.60**	28.30	7.10	2.80	**12.73**	4.00	4.20	2.60	**3.60**
99	ANKUR3224	10.90	20.50	15.20	**15.53**	32.20	9.20	2.90	**14.77**	5.90	4.20	2.90	**4.33**
100	ACH133-2	13.40	19.80	15.30	**16.17**	33.30	8.60	3.10	**15.00**	5.30	3.90	3.00	**4.07**

90 and 120 days after sowing, respectively. The highest incidence of whitefly although near to economic threshold level was recorded at 90 days after sowing. In case of thrips, the maximum population was found at 60 days after sowing and varied from 24.5 to 38.2, 6.7 to 11.1 and 2.1 to 3.6 thrips/3 leaves at 60, 90 and 120 days after sowing, respectively. At 60, 90 and 120 days after sowing, the leafhopper population varied from 3.2 to 7.8, 3.2 to 5.3 and 2.2 to 4.0 leafhopper/ 3leaves, respectively. On the basis of mean of 3 observations, the population (No./3 leaves) of whitefly, leafhopper and thrips ranged from 14.3 to 18.9, 12.17 to 16.57 and 3.17 to 5.17, respectively. Jeyakumar *et al.* (2008) also conducted the experiment of performance of *Bt cotton* against sucking pests and found that the incidence of whitefly was comparatively more than jassids.

The infestation of bollworms was not observed in any of the tested *Bt* hybrid both on green boll basis and boll/locule basis at harvest. Jeyakumar *et al.* (2008) based on their experiment found almost nil damage to the bolls in *Bt* cotton compared to non *Bt* cotton hybrid.

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ELS cotton status and strategies for enhancing production

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Gossypium barbadense, L. is commonly known as Egyptian cotton or ELS grown primarily in Egypt, Sudan and CIS countries. It is known as GISA types. Pima cotton of USA also known as extra long staple cotton widely grown in California, Arizona, New Mexico, and southwestern Texas USA which is similar to Egyptian GISA cotton. ELS cotton is generally used to manufacture high quality ring-spun yarns. Common endusers of ELS cotton include sewing thread, lace yarns, and high quality dress and shirt fabric. The term 'Extra Long Staple' (ELS) cotton typically denotes a cotton fibre of extraordinary fibre length. The recognized industry standard for the minimum fibre length of an ELS fibre is 1-3/8" or 34.925 mm. But as per the CIRCOT, Mumbai classification, staple length of more than 32.5 mm is considered as ELS category. As well as fibre length, ELS cottons are also recognized for their superior strength and better uniformity.

Global status on ELS cotton : *G. barbadense* is grown in about 10% of the cotton area and supports about 4% of the world production. The major ELS producing countries are USA, Egypt and Sudan. ELS production accounts for less than 8 per cent of total world cotton production and is primarily concentrated in 7 countries, USSR, India, Egypt, Sudan, the United States, Peru, and Israel. These countries produce more than 95 percent of the world's ELS crop. According to the International Cotton Advisory Committee (ICAC), and the Foreign Agricultural Service estimates, worldwide ELS cotton production in the current 2020/2025 marketing year is expected to fall by nearly 900,000 bales.

ELS cotton fibers are stronger and finer than upland cotton fibers. Although there are clear genetic differences between the two cotton species, the differences are often blurred by dissimilar cotton classification techniques in ELS producing countries.The current method of estimating ELS production, consumption, and trade is to identify cotton types that are generally longer than upland varieties and report the entire crop of that type as ELS. This technique allows ELS to be described by type. Example ELS types are Pima, (produced in the United States, Peru, and Israel); Egypt's Giza 45, 70, 76, & 70; India's Suvin and DCH-32; China's Xiniang 149; Sudan's Barakat; and the USSR's Tonkovoloknistyi. U.S. exports of ELS cotton totalled over 30 percent of worldwide ELS exports. The leading importer of ELS cotton is Japan, followed by Italy and Germany.

ELS cotton in India : Cotton is grown on 12.2m.ha with production of 361 lakh bales of lint during 2018-2019. Despite of good harvest, there is mismatch in demand & supply of

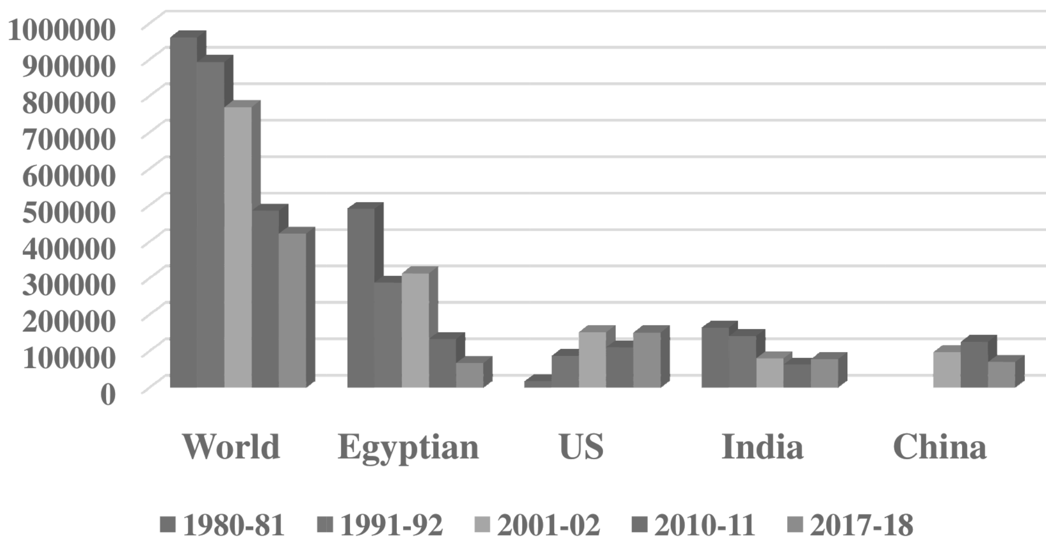

Fig. 1. ELS cotton consumption at international level (tones)

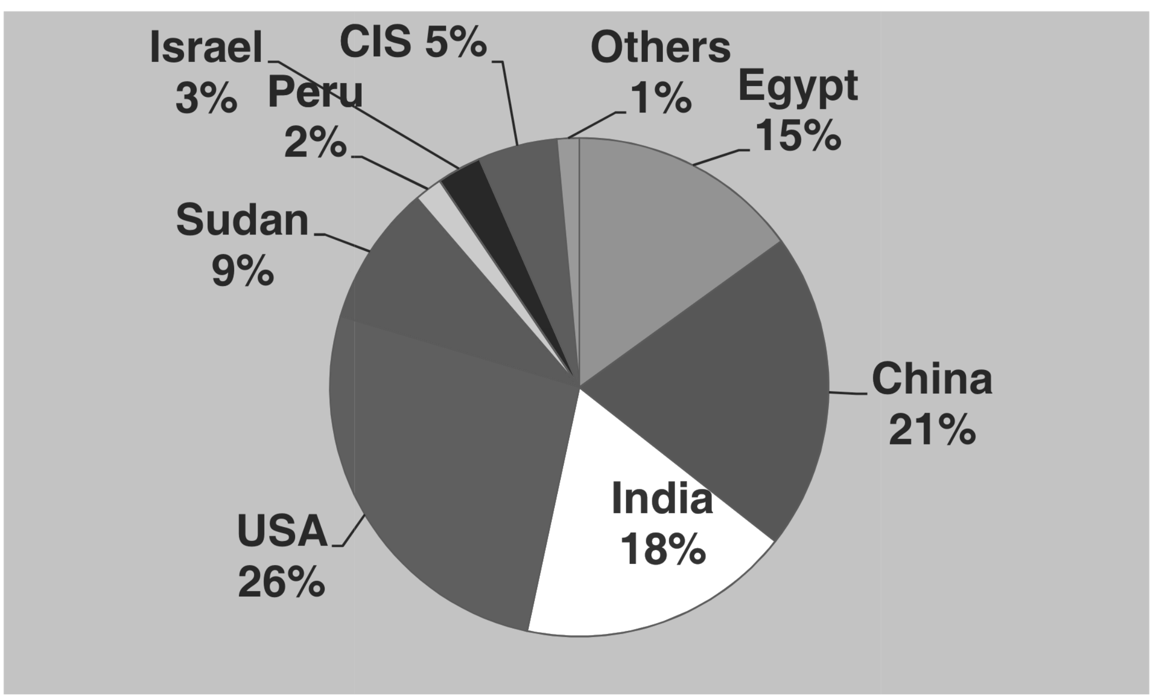

Fig. 2. ELS cotton consumption at international level

different staple group of cotton particularly in ELS cotton. The country is still importing ELS cotton annually from Egypt, Sudan, U.S.A and others. Currently about 2 lakh hectares of ELS cotton are grown in India mostly under DCH-32 in Dharwad, Haveri tract of Karnataka, Coimbatore, Erode, Dindugal districts of Tamil Nadu and Ratlam tract of Madhya Pradesh. The promising variety MCU-5 (Super fine) is grown in summer irrigated tract of Tamil Nadu, costal Andhra Pradesh and Navarangapur district of Orissa. The interspecific hybrids TCH-213, SIMA HB-3 and Sara-2 are grown in parts of Tamil Nadu and Karnataka. Phule-388 occupies negligible area in Western Maharastra.

The demand for the textile products made out of ELS cotton (32 mm and above) is growing exponentially and the potential for value addition of the products made out of these cotton varieties is very high. Though we have become very comfortable in the supply of indigenous short and medium staple cotton, the position of ELS has reached a precarious stage in our country (Basu, 2006). The production of ELS cotton has been continuously decreasing as against the increasing demand by the textile industry. Realizing the importance of strengthening the position of textile industry on this front, It is very essential to make the fine and superfine count cotton yarns available to the handloom weavers at a competitive price and also to improve the productivity and quality of the ELS cotton varieties to ensure remunerative price to the farmers. The demand for ELS cotton in India is about 9 lakh bales against the availability of only about 4 lakh bales. The requirement of this cotton is expected to be about 20 lakh bales by 2020. In India the cotton consumption rate is increasing lately at much faster rate as compared to that of 10 years ago. The shortage of ELS cotton from domestic production has been receiving the attention of the industry for quite some time. All along India has been the pioneer in producing fine and superfine count yarns and has a dominant share in the global textile trade in these varieties. During the last few years, China and Pakistan have entered into this market using the imported cotton particularly from USA and Egypt and have become the competitors for India.

In order to sustain in the global competition, it is essential to make the cotton available to the mills on par with our competitors. Therefore, it has become essential for India to give priority for increasing the ELS cotton production to retain the market share and also to improve the income of the farming community.

Summer ELS domain (rainfed) : Summer ELS domain (rainfed)exists in Coimbatore District, Tamil Nadu covers north

Table 1. ELS cotton preferred fibre quality parameters

Count range	Fibre length(mm)	UR (%)	Fibre strength (g/tex)	Elongation (%)	Mic. (µg/inch)	Maturity (%)
61s – 80s	33-34	48	29	7	3.7-4.0	80
81s – 100s	35-36	48	31	7	3.6-3.8	80
101s – 120s	36-38	48	32	7	3.5-3.8	80

block of Pollachitaluk and adjoining areas of Kinathukadavu block of Coimbatore District. The crop season starts in the month of April and reaches end in August supported by summer rain, preluding monsoon rain from Kerala border and South West monsoon. The soil is classified as sandy loam with pH of 7.4, EC of 0.19 dSm^{-1} with available nitrogen of 222.3 kg/ha, P_2O_5 of 17.3 Kg/ha and K_2O of 716.3 kg/ha. The ELS cotton of pure *G barbadense* variety or interspecific Bt hybrids is cultivated In April-September season. The ELS is cultivated as rainfed crop in summer season under sandy loam soil. The rainless period of September is coinciding with bursting and subsequent picking. The average yield of 8-10 q/acre is realized by farmers. The weather parameters of the domain revealed that maximum temperature is ranged from 29.2 to 34.6 minimum temperature ranged from 22.7 to 24.3 , relative humidity ranged from 70.3 to 85.2 per cent and solar radiation ranged from 343.8 to 544.1 cal/cm^2 . The sufficient mean rainfall of593 mm is received for successful crop production. The weather parameters are also found suitable to raise *G barbadense* cotton. The total rainfall of 1063 mm with distribution from April to November could support for double cropping under rainfed condition (sankaranarayanan and Usharani, 2018).

Reasons for inconsistent in ELS cotton production :

1. Long duration
2. Susceptibility to sucking pest, boll worms and severely to pink boll worms
3. Sterility, poor boll bursting and empty locules in suvin
4. Declining of yield in comparison to release period especially with suvin
5. High Labour requirement for harvesting and drudgery involved
6. Less suitable for rainfed because of longer duration
7. Sensitivity with water logging and Mg deficiency
8. Competition from high value crops and also within the species (*G.hirsutum*)
9. Higher production cost
10. Low and non staple market price
11. Low productivity

Strategies for enhanced ELS cotton production :

- **Increasing area under ELS cotton :** During 1980s India was very strong in ELS cotton production. The country could produce 11.46 lakh bales in ELS cotton varieties and 13.25 lakh bales in MCU5 totalling 24.71 lakh bales. Over a period, the production has fallen, the area under ELS cotton got drastically reduced and now we are facing severe shortage in these varieties.
- **Establishment of ELS Mission Directorate and SPV :** It is recommended to form a Special Purpose Vehicle (SPV) and establish an ELS Mission Directorate as a public-private sector partnership enterprise to undertake the ELS cotton promotion project. The Directorate will have a mandate to provide an effective mechanism for co-ordination between all the agencies involved in ELS cotton research and development and the textile industry.

- **Budgetary support for ELS cotton promotion :** Considering the scope for export potential, employment potential to the handloom community and enhanced income to the farmers, it is recommended to make a budgetary allocation of Rs.50 crores for the project.
- Developing location specific soil moisture conservation techniques to increase productivity of rainfed ELS cotton
- Testing of early sowing to avoid moisture stress at peak period of growth
- Developing *barbadense* genotypes with improved productivity, earliness and high ginning outturn. The quality improvement especially micronaire and strength to international standards

Table 2. ELS cotton fibre quality parameters of foreign genotypes

Variety	Fibre length (mm)	Micro-naire (/inch)	Fibre strength (g/tex)
Giza 70	35	4.2	44
Giza 88	35	4.1	45
Giza 86	33	4.4	44
Pima	38	4.5	41

- Development of intra *barbadense* hybrids to enhance productivity with ELS quality
- Development of potential interspecific hybrids (HXB) meeting the CIRCOT quality norms (35-36 mm; 3.6 micronaire; 31 g/tex) with improved yield and ginning outturn.
- Identification and precision mapping of ELS cotton growing tracts through detailed soil survey and plant – soil – water - climate relationships for enhanced productivity
- Project mode approach through contract farming of ELS
- Increase yield/ha and area under ELS cotton cultivation and ensure higher income to the farming community.
- Establish Indian ELS cotton brand in the International market.

Technological option available for ELS cotton cultivation :

Genotypes : In India, Suvin is the only ELS variety with a fibre length of 35 mm and above. The first interspecific (*G.hirsutum x G.barbadense*) hybrid, Varalaxmi was released from UAS, Dharwad. This was followed by DCH 32 in 1981 and TCHB 213 from TNAU, CBE. The interspecific hybrids are capable of spinning up to 80's count yarn. MCU5 (30-34mm)is a good long staple variety produced by India to spin 60s to 80s counts which is also considered to be ELS variety (with 32mm & above staple length). ELS Bt hybrids released by private sector *viz.,* RCHB 708 Bt, *RCH 625,* Ankur HB 1902, Ankur HB 1950, Ankur HB 1976, Ankur 2110 , MRC 6918, MRC 7918, Kasinath, NFHB 109, KDCHB 407, KDCHB 786, Minarva 904, NCHB 940, NCHB 945, NCHB 990, NCHB 991, NCHB 992, VBCHB 1010 and VBCHB 1203 may contribute towards increased ELS production in the coming years. Amongst RCH 625, MRC 7918, MRC 6918, Ankur 2110 are popular with farmers.

Weed management : In south zone, integrated weed management practice of 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 recommended for 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 pendimethalin 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). Vaiyapuri *et al*. (2007) studied the effect of growing non conventional green manures (marigold, sesamum and sunnhemp) on growth, yield and economics of TCHB 213 cotton. Intercropping of marigold in two rows in between cotton rows and incorporating it on 30 DAS had contributed ultimately more kapas, lint yield and BC ratio of cotton securing higher yield advantage in both summer and winter crops.

Split application : The trial conducted at CICR, Coimbatore (2006-2007) with ELS *Bt* hybrid (RCHB 708 Bt) found that seed cotton yields of 3570 kg/ha was recorded under 4 splits followed by 3 splits (3495 kg/ha), 5 splits (3463 kg/ha) and 2 splits (3120 kg/ha) of recommended level of N and K /ha (90:45:45 N,P_2O_5 and K_2O kg/ha). Interaction effects between the treatments did not influence the seed cotton yield significantly (Praharaj and Sankaranarayanan, 2007).

Irrigation scheduling : Trials conducted at Coimbatore and Dharwad (with MCU 5 and hybrid Varalaxmi) revealed that ELS cotton is irrigated at 75per cent depletion of available soil moisture for good yield. On climatological approach, scheduling of irrigation at 0.40 and 0.60 IW/CPE (Irrigation Water/Cumulative Pan Evaporation) ratio during vegetative and reproductive phases respectively is recommended. There was no difference in yields obtained under 0.45 and 0.60 IW/CPE ratios as well as between 40 and 60 mm depth of irrigation.Irrigation scheduled at 0.8 ETc registered significantly higher seed cotton yield in RCHB 708 *Bt* (3369 kg/ha) over that in 0.6 ETc (2794 kg/ha)as reported by Praharaj and Sankaranarayanan (2007). Both 1.0 ETc and irrigation in furrows @ 0.6 IW/CPE ratio were on par with 0.8 ETc thereby making 0.8 ETc the optimum level for drip irrigation. Fertigation at RDF registered significantly higher seed cotton yield (3345 kg/ha) over that in both (75 %RDF) (3006 kg/ha) and soil application (3063 kg/ha).

Polythene mulching : Polyethylene mulching in combination with drip system at 0.4 Etc recorded heavier bolls of 5.60 g/boll as against 4.93 g/boll under conventional method. The growth stimulating condition under poly ethylene mulching and poly mulch + drip system has resulted in significant enhancement in assimilate partitioning towards economic produce with many fold enhancement in production of harvestable bolls in cotton 'RCHB 708 Bt' contributing significantly to higher seed cotton yield ranging from 40.8 to 59.2 per cent higher yield than conventional method. The drip irrigation also enhanced the seed cotton yield ranging from 12.0 – 26.5 per cent higher yield than conventional method. The poly ethylene mulch + drip at 0.4 Etc recorded 25.9 per cent higher seed cotton yield than drip at 0.8 Etc without poly ethylene mulching (Nalayini *et al.,* 2011).

Drip irrigation : Veeraputhiran and Kandasamy (1999) reported that the seed cotton yield of TCHB 213 increase due to drip irrigation over surface irrigation was 11.6 and 20.4 per cent, respectively for winter and summer. The yield obtained with 60 kg N/ha through drip was comparable with 120 kg N/ha by conventional soil application indicating a saving of 60 kg N/ha through drip irrigation. Application of 100 and 50 per cent NPK through drip irrigation recorded comparable yield in DCH 32 and were substantially better than that obtained with flood irrigation with recommended dose of N at Nagpur. Reducing irrigation water by 70 per cent by drip irrigation method did not show any adverse effect on the growth of hybrid cotton DCH 32 compared to flood irrigation (Anon, 1997). The trial conducted at CICR, Coimbatore (2006-2007) by Praharaj and Sankaranarayanan (2007) with ELS *Bt* hybrid (RCHB 708 Bt) found that crop water use progressively increased from 0.6 ETc (39.5 cm) to 1.0 ETc (59 cm) and 0.6 IW/CPE ratio (64 cm).

Poly mulch + drip fertigation : ELS Bt cotton RCHB 708 responded favourably and significantly to poly mulch + drip and drip system as reported by Nalayini *et al.*, (2012). The enhancement in seed cotton yield was 22.8 per cent due to drip and 50.4 per cent due to drip + poly mulching. The poly mulch + drip system recorded significantly higher seed cotton yield average of 6423 kg/ha followed by drip system without poly mulch with an average seed cotton yield of 5246 kg/ha as against the lowest seed cotton yield of 4272 kg/ha under conventional method. Among the fertilization techniques, application 100 per cent of recommended NPK along with either foliar spraying of 0.15 per cent boron as solubor (twice) during flowering to boll development stages or magnesium sulphate @ 50 kg/ha as drip fertigation were on par with application of either 100 per cent of NPK or 75 per cent NPK with 50 kg each of zinc sulphate, magnesium sulphate and foliar spraying of boron (0.15 %) as solubor.

The yield maximization trial with ELS *Bt* (RCHB 708 *Bt*) hybrid was conducted at CICR, Coimbatore by Sankaranarayanan (2014) revealed that the significantly highest seed cotton yield of 29.5 q/ha was recorded with chisel ploughing + drip fertigation + foliar spraying of speciality fertilizer (19:19:19 @ 1per cent at 75 and 105 DAS and 13:0:46 @ 1per cent at 90 DAS)

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Agronomic management for rainfed cotton

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ABSTRACT : Cotton (*Gossypium* spp.) popularly known as "Wide Gold" assumed the place of pride in Indian economy. Though, 88.0 per cent area *i.e.* 103.6 lakh hectare is occupied by *Bt* cotton hybrid, nearly 60 to 65 per cent area is under rainfed condition. It is wildly recognized that the average yield of rainfed cotton, even in developed countries seldom exceed half of the theoretical potential yield, if all the rain water use efficiently. It is proposed that, this "gap" between actual and potential yield can be effectively address using existing technology that do not harm ecosystem, contrary may improve it. Agronomic practices that can improve crop yield and soil health will sustain, such improvements in the longer term are inter-link. Effective agronomic managements in rainfed cotton required planning coupled with selection of proper agro-techniques with its right time of field application. Though the main component are not universal but location specific that insure higher yield are selection of cultivar, sowing time, soil and water conservation practices, planting geometry and plant population, weed management, inter cropping and moderate use manure and fertilizer are discuss.

Keywords : Cultivar, intercropping, nutrient management, planting geometry, plant population, sowing time, soil and water conservation, weed management

Cotton (*Gossypium* spp.) popularly known as the *"White Gold"* assumes the place of pride in Indian economy. The cotton production, processing and trade in cotton goods provides employment to nearly 60 million people in the country. Though it is grown primarily for fibre in India, it become second important oil seed crop.

In India cotton grown under 108.26 lakh ha area with 345 lakh bales production and 542 kg/ha productivity (CCI, 2018). Out of these, 88.0 per cent area is occupied by *Bt* cotton hybrids. Though the area under *Bt* hybrids is increased, still nearly 60-65 per cent area is under rainfed cultivation. In India, there are nine major cotton growing state which are divided into three zones (Table-1).The seed cotton yield is totally depends upon biotic and abiotic stress occurring under rainfed condition. Good agronomic practices (gap) maximize crop productivity, improve input use efficiency and reduce negative impacts on eco-system. Further the vegetative and reproductive growth pattern are changed by introducing the *Bt* gene in *Bt* cotton hybrids than non *Bt* cotton hybrids. Therefore, agronomic management for *Bt* cotton require more attention for harvesting better yield and maintain soil health in rainfed

Table 1. Major agro-climatic zone of cotton cultivation

S.N.	Zone	States and area under	Soil type	Condition
1	North zone	Punjab, Haryana, Rajasthan	Sandy to sandy loam	Irrigated
2	Central zone	Maharashtra, Gujarat, Madhya Pradesh	Uertisols and associated soils	Rainfed- limited area irrigated
3	South zone	Tamil Nadu, Andhra Pradesh, Karnataka	Red and black soils	Irrigated and rainfed

condition.

Plant growth and yield is the function of potential of the environment and its management. Once the potential of the environmental factors is understood, through management techniques efforts have to be made to provide best possible growing conditions to achieve potential crop yields. Various agro-techniques or cultural practices developed on ecological principles help to manipulate agro ecosystem to ensure,

i. Minimum intra-specific and inter specific competition for the resources
ii. Maximum utilization of available resources pool
iii. Near optimum climatic parameters at each phonological stage
iv. Favourable conditions for germination, root growth and development of storage organs (Ahlawat and Rana, 1998).

Various agro-techniques, therefore, aim at regulating physiological functioning of the crop plants by improving the water, nutrients, light and other inputs use efficiency, providing optimum conditions to each plant to express genetic potential within the constraint of environment. Following are the agro techniques, which play key-role in improving and sustaining cotton productivity under rainfed condition.

I. **Selection of genotype** : The intensive research efforts by agricultural scientist had led to a major breakthrough in the evolution of number of high yielding and superior quality of cotton varieties/hybrids/*Bt* hybrids. The present level of yield production can further be improved by cultivating the best genotypes grown under prevailing environment condition and by adopting improved agronomical practices. It is alarming that when the *Bt* cotton hybrids reached a level of saturation in the country, yield levels plateaued off (Blaise *et al.*, 2014). One major reason is the multiplicity of hybrids available on the market that caused a mismatch of the hybrid and the soil type on which these are cultivated (Kranthi, 2012). Suitable cultivars, recommended for an agro-eco region need to be grown for realizing not only high yields but also improved fertilizer use efficiency.

The recommended hybrid / *Bt* hybrid for rainfed condition are G.Cot. Desi Hy.7 and G.Cot. Desi Hy.9 and high yielding varieties are MDH-11, G.Cot.23 and G.Cot.25. Koraddi (2004) enlisted different varieties *i.e.* Abhaditya or sahana, Laxmi, jayadhar etc. under rainfed cotton in Karnataka.

II. Land preparation and configuration : Land preparation and land configuration influences intake rate of water, reduces runoff and soil erosion, improve drainage and water use efficiency and permits timely seeding of crops.

The land should be prepared with ploughing the soil up to 30 cm depth or sub soiling the soil during summer and 1 to 2 times cross harrowing. This may help in pulverizing of soil, more conservation of moisture in the soil as well as help in reducing perennial weeds and pests from the soil. 19.76 per cent higher seed cotton yield was obtained with 30 cm depth of tillage over 10 cm depth of tillage (Patel *et al.*, 2013). 30 cm depth of tillage in cotton field decreased the bulk density and increased infiltration rate of soil (Patel and Patel, 2010).

Cotton is sensitive to water logging at seedling stage, at later stage of growth it is tolerant. Singh *et al.*, (2004) found that the ridge and furrow method of planting a better option than the flat bed method of planting. Because of improvements in the soil moisture status, the available and applied nutrients are utilized efficiently. Among land configuration i.e. broad bed and furrow, ridge and furrow, opening dead furrow and tying as well as bund formation, the higher seed cotton yield was recorded with ridge and furrow and broad bed and furrow land configuration (Patel *et al.*, 2009).

III. Sowing time : Optimum time of sowing plays a vital role in obtaining potential yield of cotton. Optimum time of sowing differs with differences in climate, crop/varieties and whether the crop is rainfed or irrigated. Normally in rainfed area the crop is sown with the onset of monsoon in the last week of June to first week of July (Anonymous, 2010). Early sown crop attains good vegetative growth as well as low incidence of bollworms resulting in high yield, whereas the late sown crop suffers due to poor vegetative growth. Study conducted at Faridkot, Punjab showed the yields were greater in the 24 April sown crop than the 5 May sown plots. Consequently, the nutrient use efficiency was greater in the early sown than the late sown crop. These clearly indicate that such non-monetary inputs also contribute to improved nutrient use efficiency (Singh *et al.*, 2013). However, reports from AICCIP indicated that delay by 20 days in sowing caused a reduction in the yield of *Bt* cotton by 18 per cent at Surat, 22 per cent at Khandwa (Singh *et al.,* 2008) and 31 per cent at Dharwar (AICCIP, 2009).

IV. Planting geometry and plant population : Cotton is grown in extremely diverse soil and agro-climatic conditions. The planting geometry and population of cotton crop vary with the plant type, it's architecture, soil fertility and moisture availability. Planting geometry play a vital role for harvesting maximum solar radiation and checking the weed growth. The transgenic bt cotton hybrids have different vegetative and reproductive growth pattern, need closer spacing and higher plant population/unit area for maximizing crop yield and to reduce weed density and dry weight (Venugopalan and Blaise, 2001; Kalaichelvi, 2008 and Bhalerao *et al.*, 2012). Lack of optimum plant stand is a major factor that affects crop yields both in the rainfed as well as irrigated cotton. The *Bt* cotton hybrids were found to perform better at closer spacing (90x45 cm) as compared to wider spacing (90x90 and 90x60 cm). The optimal plant stand not only enhances yield, but also the input use efficiency (Bhalerao and Gaikwad, 2010). Venugopalan *et al.*, (2013), showed that varieties when grown at a plant population as high as 166,000/ha, the yields are the highest for some cultivars. Similarly, Hiwale *et al.,* (2018) revealed that the plant density of 166,666 plants/ha produced significantly superior seed cotton yield (kg/ha) over plant density of 55,555 plants/ha and it was at par with plant density of 111,111 plants/ha. Thus, maintaining an optimal plant stands based on the varietal characteristic is an important feature. Bushy types are not amenable for closer row spacing, while the erect and compact types are suitable for the ultra narrow row spacing.

V. Nutrient management : Nutrient requirement of crops is decided by the rooting behaviors and foregoing ability of the varieties / hybrids, the native soil fertility, soil productivity, uptake of nutrients and potential crop yields. Considering to the soil health, the organic manure @ 10 t / ha should be applied, which help in conservation of soil moisture, improved soil structure and aeration increased microbial activity and availability of nutrients. A reduction in bulk density and an increased in aggregate stability were noticed in all the soil under organic farming compared to conventional farming (Bhanuvally *et al.*, 2010). The nutrient requirement for production of one quintal seed cotton is 6 to 7.8 kg N, 0.5 to 1.2 kg P_20_5 and 7 to 10 kg K_20. The recommended dose of desi cotton, varieties, and *Bt* hybrids are varied (60-80 kg N/ha) in rainfed condition (Venugopalan and Blaise, 2001). At Dharwad, growth, yield parameters and yield (2303 kg/ha) were significantly improved particularly with 175 % RDF compared to RDF (1986 kg/ha) under rainfed condition (Gundlur *et al.,* 2013). While, Thimmareddy *et al.,* (2013) obtained significantly higher ginning percentage (35.2%), lint index (5.6) and fibre length (32.82 mm) with (150 % RDF) over RDF alone (32.77%, 4.05, 31.68 mm, respectively), however, it was *at par* with (125 % RDF).

Introduction of *Bt* Cotton, its nutrient requirement is differing to hybrid cotton due to *Bt* cotton is relatively shorter in duration, compact crop canopy and synchronized boll brusting. *Bt* cotton required 240 kg N /ha along with 40 kg P_2O_5/ha. Nitrogenous fertilizer to be applied in four equal splits, starting from 15 to 20 days after sowing remaining three splits at an interval of 20 to 25 days depends upon favorable situation, In addition to recommended doses of fertilizer application of 3 foliar sprays of (3 % KNO_3) at squaring, flowering and boll development stage to obtained higher yield. Potassium offers strength to cotton to withstand both abiotic and biotic stresses and improved lint quality (Anonymous, 2008 and Mohan, 2013). Further, Blaise *et al.*, (2009) reported that K application may be advantageous in years with low rainfall. More recently, *Bt* hybrid cotton grown on Vertisols in Adilabad, Andhra Pradesh, was found to respond to K as high as 90 kg/ha (Blaise, 2017). This is because K requirement is high during boll formation stage and the uptake is limited during this phase, particularly under rainfed conditions. Such responses were not observed in the past with the old varieties and hybrids (Mannikar, 1993). Due to such significant responses, farmers have begun to apply potash fertilizers to their *Bt* cotton crop.

In cotton nutrition, nitrogen fixing microorganisms like, *Azotobactor, Azospirillum* and phosphorus solubilizing bacteria like, *Pseudomonas strita* and Mycorrhiza like, *Glomus fasciculatum* have play a benefit role. Seed treatment (200 g/kg seed) or soil application (5 kg/ha) of *Azotobactor, Azospirillum* and *Pseudomonas strita* are beneficial for cotton crop.

VI. Weed management : In rainfed cotton, the most critical period for crop-weed competition lies between 20 to 60 days after sowing (Shelke and Bhosle, 1990; Ayyadurai and Poonguzhalan, 2010, Patel *et al.*, 2018). Continuous rains during the cropping period resulting in inadequate weed control and low yield in cotton due to difficulties in manual weeding and interculturing operation. Thus, chemical weed control method is a promising way to control weed at initial stages of crop growth. Application of Pendimethaline @ 1.25 kg/ ha as pre-emergence effectively control the weeds in cotton. Pendimethaline @ 1.00 kg/ ha pre-emergence + *Quizalofop- ethyl* @ 0.05 kg a.i./ ha at 30 and 60 DAS were effective against the grassy weeds (Anonymous, 2010).

Mulching has enough bearing towards weed suppression in cropped and non-cropped situations. The lack of sunlight inhibits photosynthesis of the germinating weeds and causes them to die. Mulches also provide an effective barrier to weed emergence, the germinated weeds find it difficult to penetrate the thick layer of mulch. Mulching is very effective against most annual weeds and some perennial weeds such as *Cynodon daclylon, Sorghum halepense.* Mulching also serves to limit water evaporation from soil, improve tilth and reduce erosion. There was a significant increase in seed cotton yield with black polythene mulch (25 micron) when compared with non-mulched cotton (Nalayini *et al.*, 2004).

VII. Water management : In rainfed area the soil and water conservation measures include both agronomic and engineering measures. The agronomic measures are contour farming, off season, deep ploughing and providing vegetative barrier on measures, *in-situ* moisture conservation techniques i.e. ridge and furrow, basin mulching, weed control can entrance the soil moisture availability to the crop; and increase cotton yield by 50 to 100 per cent (Sivanappan, 2004). Patel *et al.,* (2013) observed that opening of alternate furrow after last interculturing is the best agro-technique for rain water management in rainfed cotton.

VIII. Inter cropping : Cotton is long duration crop having initially slow growth rate is highly amenable for intercropping with any short and medium duration crop. Cotton a deep rooted crop requires wider spacing and has little lateral spread up to 65 to 75 days. Intercropping is getting greater emphasis because of yield stability and more return/unit area even under adverse condition. Anonymous (2008) identified that cotton + beans (1:1) and cotton + coriander (1:2) in normal planted cotton and cotton + beans (1:3) in paired row planting was more suitable under rainfed condition. In traditional cotton belt, cotton based intercropping systems are popular for more tangible reasons as it covers risk. Black gram, green gram, soybean, sesamum, castor, groundnut and maize crop is highly suitable for intercropping (Patel *et al.*, 2006). At Akola (Maharashtra), seed cotton equivalent yield (1958 kg/ha) and land equivalent ratio (1.46) was recorded highest in cotton + cowpea intercropping system under dry land condition (Kumar *et al.*, 2017).

CONCLUSIONS

Effective agronomic management in rainfed cotton requires extensive planning coupled with selection of proper agronomic/ cultural techniques with its application on right time is the basis for successful rainfed cotton cultivation. The main components of the technology that ensure higher targets are, soil and water conservation, use of input responsive cultivars, planting geometry and cropping system, use of efficient production practices and moderate use of fertilizers.

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Implications of management strategies on whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) dynamics and susceptibility to commonly used insecticides in north cotton growing zone of India

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ABSTRACT : Whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) dynamics studied under unprotected conditions recorded an upsurge in whitefly incidence from 2012-2013 onwards and its peak in the form of an outbreak was seen during 2015-2016 cotton season in north cotton growing zone of India. Among the several human interventions reported to be responsible for the outbreak, changes in susceptibility of whitefly to commonly used insecticides was considered very important and need to be investigated further. The management practices adopted helped in reducing the incidence of whitefly in spite of favorable conditions for whitefly after 2015-2016 seasons especially during 2017-2018. The insecticide resistance monitoring bioassays conducted against commonly used and label claimed insecticides exhibited negligible or moderate changes in susceptibility between 2016-2017 to 2018-2019 either due to the deployment of botanicals and biopesticides at initial crop stages or induction of Insecticide Growth Regulators and insecticides with new mode of action as mid season interventions under whitefly management strategies devised after 2015-2016.

The whitefly, *Bemisia tabaci* Gennadius, is an important polyphagous and invasive pest. In north cotton growing zone of India (Punjab, Haryana and Rajasthan), in cotton, whitefly dynamics showed increased infestation since 2012 leading to a severe outbreak of whitefly in 2015-2016. The main causes of whitefly outbreak were use of susceptible hybrids, hairy or bushy genotypes, late sowing, application of high nitrogenous fertilizers, inadequate phosphorus and potassium in the soil, improper choice of control measures, faulty methods of insecticide applications, and development of resistance in whitefly against insecticides (Kranthi, 2015). Among these, resistance to insecticides in insect was adjudged one of the serious factors. Whitefly occupied 8th rank among arthropods for which resistance has been reported (FAO, 2012). The pesticide use pattern, insect incidence and crop management practices and availability of other alternate hosts in the north zone influenced resistance development. To strengthen the management strategies, studies on whitefly dynamics under unprotected conditions were conducted along with resistance monitoring to document variability in population responses to commonly used and new insecticdes.

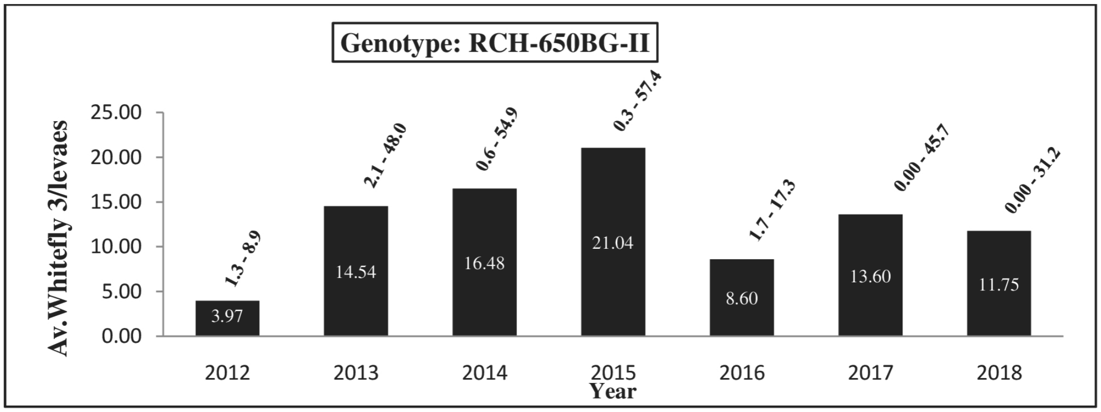
MATERIALS AND METHODS

Observations on whitefly population dynamics were recorded weekly on Bt cotton hybrid RCH 650BG-II and HS-6 (Non Bt cotton hirsutum variety), under unprotected conditions. The dynamics studies were conducted from 2012-2018 cotton crop seasons. Incidence of whitefly was also recorded from different locations on farmer's field also during 2016-2017 to 2018-2019

Study on susceptibility to insecticides through resistance monitoring were studied for three seasons ie 2016-2017,2017-2018 and 2018-2019 after 2015-2016 outbreak. Three locations of the zone covering Punjab (Abohar, hot spot for whitefly), Haryana (Sirsa), and Rajasthan (Sri Ganganagar) having maximum area under cotton were selected. The field populations of *B. tabaci* were collected through standard sampling protocol. Whitefly nymphs infested cotton leaves were collected during early morning. Infested leaflets with adaxial side downwards were placed on agar medium for the emergence of fresh adults in the laboratory at a temperature of 25±2°C with alternate light and dark period of 14:10 hours. For assessing the insecticide toxicity to *B. tabaci* adults, leaf dip bioassay were conducted (IRAC Method No 8). Fresh cotton leaves along with petiole, of uniform age, from unsprayed plants were collected. Collected leaves were dipped in the insecticidal solutions for 10-20 seconds with gentle agitation, and allowed to air dry on paper towel and kept on agar slants (2%) in insect breeding disc. Leaves dipped in only water served as control. A group of 25-30 freshly emerged whitefly adults of same age were transferred to the insect breeding dish having treated leaves. Insect breeding dishes were kept at temperature of 27 ± 2°C and humidity 60% with 16:8 lights: dark photoperiod regime. All such assays were replicated three times for a minimum of five concentrations for each insecticide. Mortality was estimated by counting the total number of dead and live insects up to 96 hours of release as described by Gorman *et al*, 2010. The adult insect was considered to be dead if no coordinated movement or deficient response to external stimulus was observed under the light microscope.

RESULTS AND DISCUSSIONS

Whitefly population dynamic and incidence studies: To know the dynamics of whitefly and its incidence level**,** population of whitefly adults was counted from three leaves, one each from upper, middle and lower strata of tagged plants in each cultivar (RCH650BG-II and HS-6) at weekly intervals. Prior to the whitefly outbreak during 2015-2016,the average whitefly adult population/three leaves in RCH 650BG-II during 2012-2013, 2013-2014 and 2014-15 ranged (mean ±SD) between 1.3-8.9 (4.0 ±2.1), 2.1-48 (14.5±13.0) and 0.6-54.9 (16.5±14.3) and in HS-6 it ranged between 0-8.2(3.5±2.3), 1.1-55.0 (14.6±11.7) and 0.4-38.9 (15.5±11.9), respectively. In 2012-2013 and 2013-2014, peak activity of whitefly was recorded during 30-31st SMW (Standard Meteorological Week) while in 2014-15 it reached highest in 37th SMW leading to a good carry over population for 2015-2016 seasons. Peak attained at late stage resulted into a good carryover for the next season especially in polyphagous pests having alternate hosts



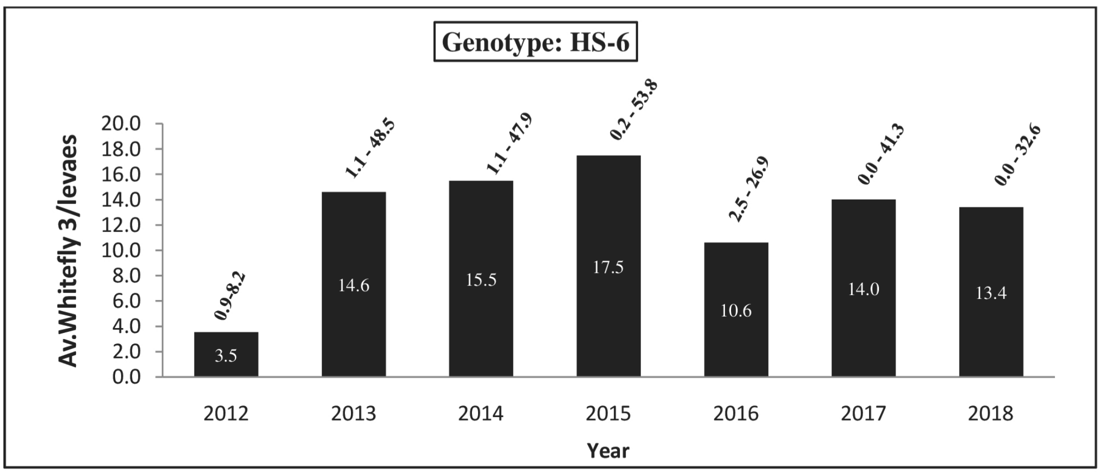


Fig. 1a & 1b. Average whitefly population recorded during the cotton season under unprotected conditions at Experimental Area of ICAR-CICR Regional Station, Sirsa from 2012-2018

available round the year.

During 2015-2016, 2016-2017, 2017-2018 and 2018-2019 adult population per three leaves ranged (mean ±SD) between 0.3-57.4(21.0±15.2), 1.7-17.3 (8.6±5.1), 0-45.7(13.6±12.4) and 0-31.2(11.8±8.0) in RCH-650BG-II and 0.2-53.8(17.5±15.6), 2.5-26.9(10.6±7.0), 0-41.3(14.0±11.7) and 0-36.4 (13.4±9.7) in HS-6, respectively. During 2015-2016, 2016-2017, 2017-2018 and 2018-2019 peak activity of whitefly was recorded between 31-32nd SMW **(Fig.1a and b)**. The results indicated that an upsurge in whitefly incidences started from 2012-2013 onwards which reached its peak during 2015-2016 with additional association of other factors that ultimately led to outbreak of whitefly. However, the management practices adopted helped in reducing the incidence of whitefly after 2015-2016 seasons.

In surveys conducted at farmer's field locations, on different *Bt* hybrids during 2016-2017, 2017-2018 and 2018-2019 season, 4 out of 128, 14 out of 160 and 16 out 179 locations recorded adult populations above economic threshold level (ETL), respectively and incidence at these locations ranged (whitefly/3leaves)

Table 1. Incidence of whitefly at different locations surveyed by ICAR-CICR Regional Station Sirsa during 2016-2017, 2017-2018 and 2018-2019.

States (SMW)	2016-2017 (128 locations	2017-2018 (160locations)	2018-2019 (179 locations)
	Pest condition	(Range/3 leaves)	
Haryana (26 &27)	0-30	1.3-6.2	0-8.0
Punjab (26 &27)	1-15.6	0.3-0.9	1.0-4.0
Rajasthan (26 &27)	1-30	1.3-7.6	0-7.0
Haryana (28 &29)	2.1-12.6	1.1-13.0	1.0-18
Punjab (28 &29)	**0-34.5**	1.1-11.6	0 -9.3
Rajasthan (28 &29)	0-15	2.3-23.6	3.0-8.0
Haryana (30&31)	0-17	**6.3-49.7**	1.0-25.0
Punjab (30&31)	0.10-36.10	27.6-43.2	0-14.7
Rajasthan (30&31)	0-8.0	7.5-17.8	0 -16.8
Haryana (32&33)	2.1-16.1	2.2-22.3	1.0-30.0
Punjab (32&33)	7-20.6	3.0-17.2	0 -20.6
Rajasthan (32&33)	0-7	4.5-28	**3.0-35**
No of locations crossed ETL	**4**	**14**	**16**

between 0-34.5,0-49.7 and 0-35, respectively. However, management strategies adopted helped in maintaining populations below ETL and reduction in incidence where it crossed ETL **(Table 1)**

Resistance monitoring to study change in susceptibility to insecticides: Insecticides are often indispensable for the management of insect pests and target insects need to be susceptible to insecticides for the latter to be effective. Evolution of pest resistance to pesticides threatens agriculture worldwide with resistance recorded in at least 546 species of arthropod pests, 218 species of weeds and 190 species of plant pathogens (Whalon *et al.,* 2013). Now in India, insecticide resistance has been encountered in 17 pest species in field and 8 pest species in storage (Radhika and Subbaratnam, 2002). The changes in susceptibility to insecticides through resistance monitoring bioassays in whitefly were conducted on insecticides popular with farmer and new chemistries deployed for the control of sucking pests in north Zone for three seasons.

Organophosphates : For chlorpyriphos 20EC formulated product lowest LC_{50} value of 5.83-12.6 (ml/litre of water) was obtained from Sirsa. However highest LC_{50} value 7.14-17.0 was found in population collected from Abohar, which was followed by Sriganganagar with LC_{50} value of 8.96-14.41. LC_{50} for ethion 50EC, 5.96-7.76 in Abohar, 4.3-8.30 in Sriganganagar and 3.02-9.8 at Sirsa; for profenphos 50EC, 0.02 - 0.07 in Sriganganagar, 0.12-0.19 in Abohar and 0.10-0.74 in Sirsa; for triazophos 40EC, 2.25-7.1 in Sirsa, 5.24 -7.71 in Sriganganagar and 6.79-8.20 ml per litre water in Abohar.

Among the organophosphates, triazophos recorded the highest resistance ratio in comparison to Nagpur population designated as susceptible population being less exposed to insecticides. Maximum resistance ratio was in Abohar population during 2016-2017, 2017-2018 and 2018-2019 ie 43.15, 40.79and 35.73 followed by, Sirsa 37.37, 11.84 and 32.10 and Sriganganagar 28.94, 40.58 and 27.57 respectively. In triazophos at Sirsa resistance ratio was higher during 2016-2017(37.37folds), decreased to moderate in 2017-2018 and again increased in 2018-2019(32.10 folds).In Abohar and Sriganganagar resistance ratio remained higher during the study period. Similarly the resistance ratio obtained in case of ethion (1.84-5.98), chlorpyriphos (3.86-11.26) and monocrotophos was moderate. The change in resistance ratio is affected not only by the insecticide use pattern in main crop (cotton) but on other alternate hosts also. Higher intensity of the insecticides use (frequency, dose, space) leads to genetically based resistance in insects over time (Tabashnik *et al.*, 1989), very high levels of resistance to monocrotophos noticed by Ahmed, 2015 and Naveen *et al.* 2017 in Indian *B. tabaci* populations, could be attributed to the large scale use of this OP compound in other crops. Rresistance ratio of all OP compounds except triazophos in the north zone was moderate (below 20 folds) during these seasons (2016-2017, 2017-2018 and2018-2019) as these insecticides were used to lesser extent after 2015-2016 outbreak of whitefly.

Neonicotinoid : The neonicotinoid were among the most sought after insecticides till 2015-2016 but now a change in insecticides use pattern has occurred and farmers are using more Insect Growth Regulators (IGRs) based and insecticides with new modes of action. Among neonicotinoid**,** in acetamiprid20SP LC_{50} value (g per litre of water) obtained from formulated product was 0.43-4.81 in Sriganganagar , 1.2-6.29 in Sirsa and 4.54-7.18 in Abohar, in thiacloprid 21.7SC 0.47-0.8 in Abohar, 0.28- 0.96 in Sriganganagar and 1.47-4.8 in Sirsa, in Thiamethoxam25WG 3.2 - 5.66 in Sriganganagar, 2.59 -13.07 in Sirsa and 5.07-14.74 in Abohar, in clothainindin 50WDG 0.25 -0.78 in Sirsa, 0.18- 1.01 in Sriganganagar and 0.68- 1.07 in Abohar, in dinotefuran20SG, 0.05-0.08 in Sriganganagar, 0.10- 0.32 in Abohar and 0.07-0.89 in Sirsa. No changes in susceptibility of these insecticides to whitefly was recorded except thiamethoxam with higher resistance ratio (RR) of 10.34 -52.28 at Sirsa followed by 20.3-58.96 at Abohar and 12.80- 22.60 at Sriganganagar (**Table 2**). In thiamethoxam at Sirsa resistance ratio (52.28 folds) was higher during 2016-2017 and reduced to moderate level during 2017-2018 and 2018-2019. But in Punjab (Abohar) resistance ratio (folds) was highest during 2016-2017(58.96), 2017-2018(51.48) but decreased to moderate level of 20.3 folds during 2018-2019. In Sriganganagar also resistance ratio was moderate (12.80-22.60 folds) throughout the study period concluded the impact of management strategies.

The neonicotinoid especially in cotton are used as foliar application and for seed treatment (Kranthi, 2012).There is a need for regular monitoring of insecticide resistance status in diverse *B. tabaci* genetic groups in India because insecticide resistance is also regarded as major driving force for the selection and establishment of specific *B. tabaci* genetic groups in a region (Wang *et al.*, 2010; Horowitz *et al.*, 2005, Naranjo *et al.*, 2010)

Synthetic pyrethroid : Among synthetic pyrethroid, bifenthrin10EC formulated product used in cotton and other crops, and resistance

Table.2. Resistance ratio (folds) and LC_{50} g or ml per litre water)in whitefly collected from hot spot areas of North Zone against commonly used insecticides (2016-17,2017-18 & 2018-2019).

Treatment	Nagpur	Sirsa						Abohar						Sri Ganganagar					
		2016-2017		2017-2018		2018-2019		2016-2017		2017-2018		2018-2019		2016-2017		2017-2018		2018-2019	
		LC50	RR	LC50	RR	LC50	RR	LC50	RR	LC50	RR	LC50	RR	LC50	RR	LC50	RR	LC50	RR
Acetamprid 20SP	**0.43**	1.20	2.79	6.29	14.63	2.46	5.72	5.00	11.63	7.18	16.70	4.54	10.6	0.43	1.00	4.81	11.19	3.51	8.16
Thiacloprid 21.7 SC	**-**	4.80	-	1.74	-	1.47	-	0.39	-	0.47	-	0.8	-	0.28	-	0.95	-	0.96	-
Thiamethoxam 25WG	**0.25**	13.07	52.28	2.59	10.34	3.71	14.8	14.74	58.96	12.87	51.48	5.07	20.3	3.20	12.80	5.65	22.60	5.66	22.6
Clothianidin 50 WDG	**1.09**	0.39	-	0.25	0.23	0.78	0.72	0.68		1.01	0.93	1.07	0.98	0.18		0.95	0.87	1.01	0.93
Dinotefuron 20SG	**0.05**	0.89	17.80	0.07	1.46	0.21	4.24	0.10	1.94	0.31	6.20	0.32	6.4	0.05	0.96	0.08	1.60	0.07	1.7
Chlorpyriphos 20EC	**1.51**	12.60	8.34	11.42	7.56	5.83	3.86	17.00	11.26	15.80	10.46	7.14	4.73	14.41	9.54	12.34	8.17	8.96	5.93
Ethion 50EC	**1.64**	9.80	5.98	3.02	1.84	6.42	3.91	6.80	4.14	7.76	4.73	5.96	3.64	4.30	2.62	5.75	3.51	8.30	5.06
Monocrotophos 36 SL	**0.40**	1.20	3.00	-	-	2.23	5.57	2.60	6.50	-		2.38	5.95	2.44	6.10	-	-	2.82	7.05
Profenophos 50EC	**-**	0.10	-	0.74	-	0.49	-	0.19	-	0.18	-	0.12	9	0.05		0.02	-	0.07	-
Triazophos 40EC	**0.19**	7.10	37.37	2.25	11.84	6.10	32.10	8.20	43.15	7.75	40.79	6.79	35.73	5.50	28.94	7.71	40.58	5.24	27..57
Flonicamid 50WG	**0.30**	4.40	14.67	0.38	1.25	0.91	3.03	0.56	1.87	0.64	2.13	1.07	3.56	0.38	1.27	0.14	0.47	0.47	1.56
Diafenthiuron 50WDG	**0.03**	4.90	163.30	1.07	35.70	1.56	52	2.30	76.67	3.73	124.33	2.34	78	2.90	96.67	3.84	128.00	1.67	55.6
Fenpropathrin 30EC	**0.45**	1.20	2.67	-	-	0.81	1.80	1.60	3.56	-	-	0.88	1.95	0.46	1.02	-	-	0.21	0.46
Bifenthrin 10EC	**0.08**	0.52	6.50	1.85	23.13	1.14	14.25	10.66	133.30	3.48	43.50	2.23	27.87	0.05	0.63	1.82	22.75	0.97	12.12

(-): Not done, Ngp (Nagpur) : - Nagpur population bioassays done during 2015-16 designated as susceptible being less exposed to insecticides ratio in bifenthrin ranged between 0.63- 22.75 in Sriganganagar, 6.50-23.13 in Sirsa and highest 27.87-133.30 in Abohar during 3 years of study, respectively. The higher resistance against bifenthrin at Abohar in whitefly may be due to its use in vegetable and fruit crops. Low to moderate (resistance ratios ranged from 5 to 45 fold) resistances to cypermethrin reported in the *B. tabaci* populations from Southern zone indicate predominance of Asia-I in this zone (Ellango, 2015, Kranthi *et al*., 2002, Naveen *et al*., 2017).

Insect growth regulator : The introduction of IGRs has also helped in effective management of whitefly as younger stages are generally more sensitive to insecticides as compared to older stages especially higher toxicity to first and second instars larval stages (Prabhaker et al. (1989). Bioassays conducted on whitefly adults recorded LC_{50} from the available formulated product of Flonicamid50WG was 0.14-0.47 in Sriganganagar, 0.56 - 1.07 in Abohar and 0.38-4.40 g/l water in Sirsa with low to moderate resistance ratio at all the locations. LC_{50} obtained with diafenthiuron 50WDG was 2.30 - 3.73 in Abohar, 1.67- 3.84 in Sriganganagar 1.07-4.90 gram per litre water in Sirsa. Higher resistance ratio obtained in difenthiauron 76.67-124.37 at Abohar and 55.6- 128.0 at Sriganganagar 35.7 -163.30 at Sirsa during 2016-2017, 2017-2018 and 2018-2019 is a cause for concern that warrant the judicious use of this insecticide. In diafenthiuron severe resistance reported in Sirsa (163.3 folds) but reduced during subsequent years. In Abohar (76.67-124.33) and Sriganganagar (55.6-128.0) resistance ratio remained higher during 2016-2017 but it reduction to 55.6 in Sriganganagar indicate the impact of whitefly management strategies.

The management strategies devised and adopted in the zone reduced incidence after 2015-2016 whitefly outbreak and also helped in sustaining the susceptibility of whitefly to commonly and newly introduced insecticides.

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Extension strategies to reduce the yield and knowledge gaps in cotton

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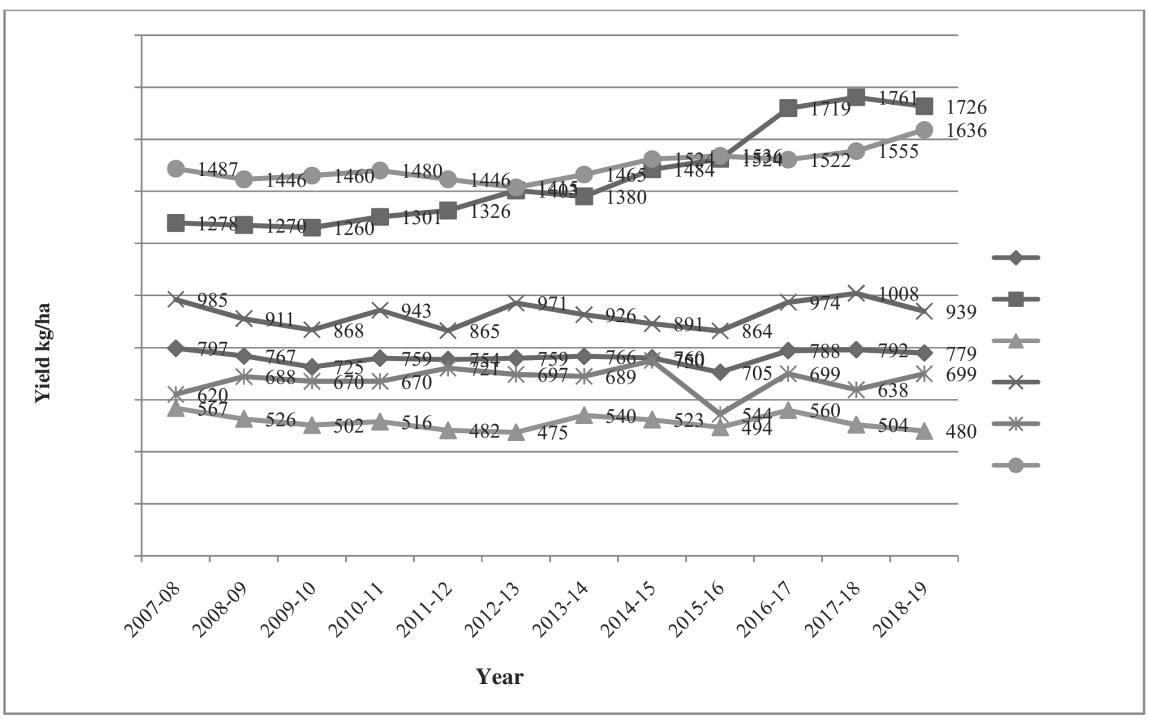
ABSTRACT : Cotton yields are stagnated for the past few years due to various factors. Cotton research system has released many technologies to improve the yield under various conditions. But there is always a gap between the potential yield of the technologies claimed by the technology inventors and the actual yield realized by the farmers in the fields. Studies say that the yield gap between potential and realized yield on farmers field is more than 30%. Analysis on yield enhancement due to the age old cotton extension program Front Line Demonstrations revealed that an average of 18.70 per cent increase over the normal farmers' practices was obtained in various locations. So there are possibilities of bridging the gap in cotton yield by properly identifying the causes of gap, appropriate management options to close the gap, fitting Transfer of Technology (TOT) innovations to disseminate the gap reducing technologies and implementing the package in the poor small and marginal farmers' fields. Similarly a gap exists among the cotton growers about the knowledge of novel yield enhancing cotton cultivation technologies. Hence, to assess the yield gap in cotton between potential, actual and attainable yields, to appraise the knowledge gap among cotton growers, to find out the reasons for the yield and knowledge gaps and to propose appropriate TOT innovations to reduce the gaps an extension study was conducted. Analysis of yield gap in cotton using the available secondary data from 2006-2007 to 2018-2019 revealed that there is a need to increase an average of around 700 - 750 kg /ha seed cotton yield in the coming years to reduce the yield gap between India and world. Similarly, it is found that through FLD like TOT interventions we can reduce the yield gap between world average and Indian average to a tune of 49 per cent. Considering the result, extension strategies which can reduce the knowledge gap and thereby the yield gap between world average and Indian average to a tune of more than 50 per cent are explored in this paper.

Cotton is one of the important commercial crops cultivated in India. Even though, India has the laurels of having top places in acreage and production of cotton, the concern is always about its productivity. For the past twelve years, the average cotton lint yield of the country ranged from 475 to 567 kg/ha. Particularly, for the past five years, it is stagnated around 500 kg/ha. Every year, the country's cotton research system both in public and private, release many high yielding varieties/ hybrids, yield enhancing agro technologies and management strategies for damages caused by the insects, diseases and deficiencies. But there is always a gap between the potential yield of the technologies claimed by the technology inventors and the actual yield realized by the farmers in the fields. To study the reasons behind this gap, many attempts have been made by the cotton scientists and the studies revealed that the knowledge gap was the major reason in addition to the other researchable and non researchable factors. So, to bridge up the yield gap in cotton, at first, the knowledge gap has to be bridged up. To bridge up the knowledge gap, novel extension innovations need to be developed to speed up the reachability of cotton technological information to the unreached in appropriate forms.

Yield : In Agriculture, the word "Yield" in noun form refers to the measure of produce from a crop per unit area of land cultivation per season. Measuring the yield is important since it gives understanding about the status of food and fibre security in a country. It is common to consider yield as an indicator of production competitiveness for a country or an indicator of its profitability for the producers (Fok, A. C. M., 1998). To summon up the evolution of yield criteria, before agriculture, our ancestors were not unlike other animals, for which "yield" was the ratio between the energy derived from food and the energy invested in obtaining it. Once the sowing of crops was established as a common practice, the definition of yield shifted from an energy ratio to the ratio between the numbers of seed harvested and seed sown (Evans 1993). There are different types of yields as regards agriculture. Theoretical yield is the maximum



(Source: ICAR- AICRP (Cotton) annual Reports (2006-07 to 2018-19))

Fig. 1. Average Cotton Lint Yield of Global and Five Major Cotton Growing Countries from 2001-08 to 2017-18

Table 1. Average Cotton Lint Yield of Eleven Cotton Growing States in India from 2007-08 to 2017-18

States	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018 (P)	2018-2019 (P)
Punjab	563	565	452	593	607	744	800	526	313	536	672	688
Haryana	528	522	495	587	690	719	761	603	401	611	571	690
Rajasthan	415	422	421	513	651	642	605	593	569	595	640	754
Gujarat	772	650	635	686	700	633	837	687	562	678	674	577
Maharashtra	330	335	306	378	313	332	341	324	307	396	343	334
Madhya Pradesh	540	490	422	463	433	531	628	563	544	582	578	585
Andhra Pradesh	690	644	596	538	543	595	555	549	606	684	541	617
Karnataka	337	375	358	346	460	596	590	661	516	600	576	532
Tamil Nadu	687	780	746	1003	831	797	559	545	718	599	505	729
Telangana								501	556	579	493	502
Odisha				471	583	571	548	401	408	375	410	484

P –Provisional (Source: ICAR- AICRP (Cotton) annual Reports)

crop yield as determined by biophysical limits to key process including biomass production and partitioning. It can be estimated with models with sound physiological structure, and parameters reflecting the biophysical boundaries of key processes (Sadras *et al.,* 2015). Potential yield is the yield of a current cultivar “when grown in environments to which it is adapted; with nutrients and water non limiting; and with pests, diseases, weeds, lodging, and other stresses effectively controlled (Evans and Fischer 1999). Water-limited yield is similar to yield potential, except that yield is also limited by water supply, and hence influenced by soil type (water holding capacity and rooting depth) and field topography. This measure of yield is relevant to benchmark rainfed crops (Sadras *et al.,* 2015). Realized or Actual Yield reflects the yield obtained with the current state of soils and climate, average skills of the farmers, and their average use of technology (FAO and DWFI. 2015). Attainable yield is the best yield achieved through skilful use of the best available technology (Hall *et al.,* 2013).

Yield gap : It is always a matter of concern for the research managers and development administrators to ensure that the real potential of any crop variety is harvested at the farmers’ field. In reality, however, a gap always prevails between what is projected as the potential yield of any variety at research station and what is obtained on organized farm trials and further what is harvested by the farmers themselves. Many the times at field level the farmers could not realize the yield potential in any crop. By definition, yield potential is an idealized state in which a crop grows without any biophysical limitations other than uncontrollable factors, such as solar radiation, air temperature, and rainfall in rain-fed systems. Therefore, to achieve yield potential requires perfection in the management of all other yield-determining production factors from sowing to maturity. Such perfection is impossible under field conditions, even in relatively small test plots let alone in large production fields (Lobell *et al.*, 2009). Technically, this is referred as yield gap of different types. Several researchers defined yield gap in many ways depending on their objectives of the study. The yield gap is defined as the difference between the maximum-attainable yield and the farm-level yield (Jha *et al.,* 2011). Also it is referred as the difference between any two levels of yield (FAO and DWFI. 2015).

Global cotton yield : An analysis on twelve years yield data of global and top five cotton growing countries was done using the secondary data published in ICAR-AICRP (Cotton) annual reports (Fig. 1). It reveals that even though India is holding the largest acreage in cotton and leading in production for few years, it is far behind in terms of its average productivity. The yield over a decade has been stagnated and it's always around 500 kg lint / ha. But, China, the present global leader in cotton production has been increasing its average yield every year. Similarly, Brazil has consistently been maintaining its average cotton lint yield around 1500 kg/ha over the years.

Cotton yield in India : In India, eleven states are growing cotton every year. An analysis on twelve years yield data of cotton growing states in India was done using the secondary data published in ICAR-AICRP (Cotton) annual reports (Table 1). It reveals that few states like Punjab, Haryana, Rajasthan, Gujarat and Tamil Nadu are having average yield nearly close to the world average cotton yield. Cultivation under irrigated condition is a major factor favoring the yield in these states. The average yield of Maharashtra state needs to be improved with best technological and extension innovations since it has the largest area under cotton in the country.

Yield gap in Cotton : An estimate says that the yield gap between potential and realized yield on farmers field is more than 30 per cent. Cotton crop is not an exception for that. Cotton Yield is stagnating at world level, in developed countries or in developing countries, either under irrigation or not. In a limited number of countries, yields actually reached are close to potential yields, however, in many countries, actual yield are still far from potential ones (Fok, A. C. M., 1998). In cotton, the mean yield gap between simulated rainfed potential yield and state average yield was 1120 kg/ha. This yield gap at the experimental station level was only 640 kg/ha (Aggarwal, 2008). Analysis on yield enhancement due to FLD revealed that an average of 1631 kg/ha seed cotton yield was obtained in the demonstration which was 18.70 per cent increase over the normal farmers' practices of the locations. The average yield gap observed between the FLD and normal farmers' practices was 257 kg seed cotton yield (Usha Rani and Prakash, 2016). Since, analysis of yield stagnation is considered as a tool to clarify the issues cotton research has to address in order to modify the current yield trends (Fok, A. C. M., 1998), Indian cotton research system has the responsibility to analyze and come out with solutions.

Study on cotton yield gap at ICAR Central Institute for Cotton Research : A study to assess yield gap in cotton between the potential, actual and attainable yields, the knowledge gap among cotton growers, to find out the reasons for the yield and knowledge gap and to propose appropriate TOT innovations to reduce the gaps is being conducted in ICAR-Central Institute for Cotton Research. In the study, the global average yied and indian average yield over twelve years (2006-2007 to 2017-2018) were compared and the results revealed that there was a range of 220 to 268 kg/ha cotton lint yield gaps over the years (Fig. 2).

Similarly, the FLD average and national average seed cotton yield of Cotton was collected from 2006-2007 to 2017-2018 from the sources (CAB and FLD Annual Reports published by PC (Cotton Improvement) ICAR-AICRP (Cotton)) and analyzed. The average FLD yield during the reported period was 1686 kg/ha as against the national average of 1329 kg/ha. The average yield gap (SCY) between FLD average (Potential Farm yield / Attainable yield) and National average (Actual yield) was 357 kg/ha.

Similarly, the average Seed Cotton Yield of FLD and Farmers' practices were collected and analyzed. The average FLD yield during the period was 1686 kg/ha as against 1433 kg/ha of farmers' practices. The yield gap between FLD and farmers' practices was 254 kg/ha. From the results, it is interpreted that through FLD like TOT interventions we can reduce the yield gap between world average and Indian average to a tune of 49 per cent. Identifying a better TOT intervention than FLD which can reduce the yield gap between world average and Indian average to a tune of 100 per cent is the need of hour.

Reasons for yield gap in cCotton : Yield stagnation is may be due to few localized climatic constraints, technological constraints,

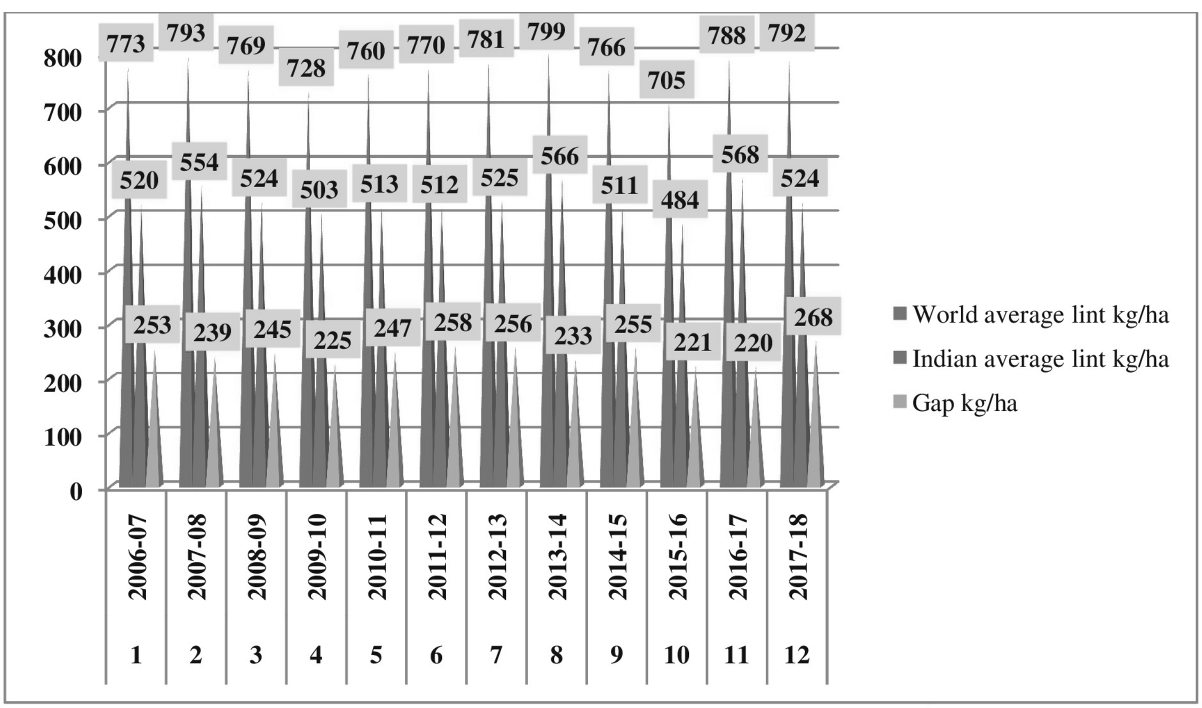


Figure 2: Yield gap between Global and Indian Average Cotton Lint yields from 2006-07 to 2017-18

extension constraints, constraints related to availability of quality inputs and structured credit facilities, etc., But, extension research studies on analysis on the reasons for yield gap in cotton revealed that the knowledge gap also contributes significantly in addition to all other factors. Knowledge by definition is a highly organized intellectual product of humans that includes personal experience, skills, understanding of the different contexts in which we operate our activities, assimilation of all these and recording all this in a form that could be communicated to others. This communication of recorded experience, data, information, etc., makes for further of growth. “Knowledge Gap” is the gap between available technological information in the research stations and reached technological information at farmers’ level. When exploring about the knowledge gap studies in agriculture, the knowledge gap theory suggests that information is obtained more efficiently by those who have a higher socio-economic status rather than those who have a low socioeconomic status. Mass media infusion is absorbed at different rates across different socioeconomic groups, thus impacting the rate of information obtained by individuals (Tichenor *et al.,* 1970). As home computer ownership and Internet access has increased, it has been suggested that knowledge gaps have decreased (Hindman, 2000). However, despite access to computers and the Internet, knowledge gaps continue to exist because people continue to lack comprehension of information and/or the technology (Chadwick, 2006). A lack of motivation to cognitively digest certain information has also been discussed as contributing to knowledge gaps (Weenig & Midden, 1997). Knowledge gap is closely related to the digital divide, suggesting those who have lower incomes and reside in rural areas have less access to media outlets. Alternatively, those with higher levels of education, higher income, and residence within an urban or suburban location, generally have abundant media access (Rainie *et al.,* 2003). This type of knowledge gap due to reachability of information to the unreached in appropriate form demands for novel extension innovations.

Extension strategies to reduce the yield and knowledge gaps in cotton : To have yield be improved, there is either to extend the existing yield potential or to decrease the gap to existing potential yield (Fok, A. C. M, 1998). To extend the existing yield potential we need to extend the technologies. Technologies make a difference. Cotton is one of the crops tremendously influenced by the technological breakthroughs. Technologies with genetic modification, inter specific and intra specific hybrids / varieties, novel pesticides, management of diseases, insects and nematode pests, weeds, nutrients, soil, water and climatic aberrations and mechanization can contribute significant increase in the yield (Kranthi, 2015). The extension of existing yield potential of new technologies and the existing large gap between the potential yield and yields that farmers achieved can be bridged up with the use of appropriate TOT innovations with due consideration to the constraints under which the technologies are not suitable for farmers. In this direction, ICAR- CICR has already been executing many extension programs *viz.,* Front Line Demonstrations in Cotton, *e-Kapas* mobile phone based cotton advisory service, weekly cotton advisory service in CICR website, Cotton Mobile App etc., and disseminating technological information to many of the unreached cotton growers in eleven cotton growing states in the country. Continuously, the extension scientists in ICAR-CICR are working on developing new outreach tools to reduce the knowledge gap. Currently, they are on a new approach called “Synergistic TOT approach in Cotton”.

CONCLUSION

Cotton research system has released many technologies to improve the yield under various conditions. But there is always a gap between the potential yield of the technologies claimed by the technology inventors and the actual yield realized by the farmers in the fields. Analysis on yield enhancement due to cotton extension programs proved that 49 per cent of the yield gap between world average and Indian average can be bridged up. So there are possibilities of bridging the gap in cotton yield by properly identifying the causes of gap, appropriate management options to close the gap, fitting TOT innovations to disseminate the gap reducing technologies and implementing the package in the poor small and marginal farmers' fields.

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Business perspective and entrepreneurship opportunities in cotton stalk by-product based industry in India

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Cotton is grown in about 100 countries and traded in around 150 countries worldwide. Cotton is an important commercial crop of India and it is the largest producer in the world with its production of 6.15 million tons in 2017-2018. Cotton is cultivated mainly for its fibre which is the most important commercial product apart from the cottonseed and cotton stalks as its valuable by-products. Around 11million tonnes of cottonseed and about 30 million tonnes of cotton stalk is generated in India every year. Linter, hull and meal are the important by-products obtained after extracting oil from the cottonseedwhich are used for preparation of value added products.

In India very limited value addition is done to cotton stalk. Most of the cotton stalk produced is treated as waste, though about 5-6 per cent being used for commercial purposes and around 15-20 per cent is used as fuel by rural masses and remaining bulk of cotton stalk is burnt off in the field after leading to severe environmental pollution.

Cotton by-products based industries are underdeveloped in India owing to several impediments, including, lack of logistics for supply of cotton stalk, lack of availability of equipment for uprooting and chipping, lack of awareness and information among the farmers about value added technologies, inadequate government policies to support the development of cotton by-product industries etc.

Cotton Stalk

Domestic Fuel

Burning in the field

Cotton stalk is comparable to the most common species of hardwood in respect of fibrous structure and chemical composition. Cotton stalk contains 60 per cent hello cellulose, 27 per cent lignin and 6 per cent ash. The calorific value of cotton stalk is about 4000 kcal/kg. ICAR-

Central institute for Research on Cotton Technology (CIRCOT), Mumbai has developed techno-economically viable technologies and commercialized various technologies for value addition to cotton by-products. As cellulose and lignin content is more in cotton stalk, it can be used for making particle boards. The cotton stalk can be used for manufacture of briquettes and pellets as renewable source of energy and power generation as it has good calorific value. Cotton stalk can be converted to bio-enriched compost and can be used to cultivate edible mushroom.

The economic business opportunities can be realised by establishing cotton by-product based industries to move towards sustainable development and also to create entrepreneurship and generate employment in rural areas in cotton sector.

Business model for supply chain of cotton stalk for industrial applications : Lack of viable logistic model for supply of chipped cotton stalks to the industries is a cause for non-utilization of cotton stalks for industrial applications. Traditional method of uprooting cotton stalks with a traditional tool (*Chimta)*is very tedious and labour intensive process. Hence, it was not viable for supply of cotton stalks for any industrial uses. Therefore viable logistics model have been developed for supply of cotton stalks for pelleting, briquetting and power generation industries.

The viable supply chain model comprises of uprooting of cotton stalk by tractor operated V-type up-rooter, followed by sun drying, shredding by a tractor operated shredder and transportation of chipped cotton stalk with truck/tractor to briquetting and pelleting plant within the radius of 50 km. Chipped cotton stalk fetches price of Rs. 2500-3000/tonne at factory gate. Additional remuneration of Rs. 1500-2000/tonne to the cotton farmers, thus contributing to doubling famer's income.

This cotton stalk supply chain model has been demonstrated to farmers and stakeholders, pelleting, and briquetting and power generation industry in Vidharbha region of Maharashtra. It resulted in creation of employment and

Cotton Stalk

Cotton stalk chipper

entrepreneurship opportunities for rural youth in cotton growing regions. Around 50 briquetting and pelleting plants based on cotton stalks have been established in and around Nagpur.

Entrepreneurship opportunities to manufacture cotton stalk based briquettes and pellets : Briquetting and pelleting technologies are well developed and widely used commercially in developed countries. But lack of knowledge of technology and technical constraints was the causes for less adoption of this technology in India. The calorific value of cotton stalk is about 4000 kcal/kg hence it can be used for manufacture of briquettes and pellets which can be used as a renewable source of energy. To address these issues extensive research work was done to develop process protocol and value added products *viz.,* briquettes and premium grade pellets from cotton stalk. Briquettes and pellets are prepared by densification at high temperature and pressure.

Briquettes find its application as an alternate fuel to coal and LPG in boilers in the sugar, paper, rubber, chemical and food processing industry. Briquettes also find application in power generation plant in place of coal. Besides this briquettes can be used in forging, furnaces and brick kiln and gasification. Cotton stalk briquettes can be used an alternate to wood for burning dead bodies which would help to reduce dependence on wood for cremation purpose. For establishment of briquetting plant with a capacity of 20 tons/day, an investment of Rs. 25 lakh is required for machinery. The return on investment in briquetting plant of capacity 20 tonnes/day is around 40 per cent and payback period is around 2 years.

Pellets are being used in cooking stoves as fuel for preparation of snacks and cooking of meals, especially in roadside *dabhas,* restaurants, etc. The utilization of pellets for cooking saves over 50 per cent costs on fuel as compared to LPG gas price. Pelleting plant of capacity 3 tons/day can be established with an investment of Rs. 15 lakhs for machinery. The return on investment in pelleting plant of 3 tonnes/day is around 25 per cent and payback period is around 3 years.

Cotton farmers also get benefitted by Rs

Cotton Stalk briquettes

Cotton stalk pellets

1500-2000/ tonne by selling of cotton stalksproduced in their field.The utilization of cotton stalks based briquettes and pellets is a step towards doubling the farmer's income. The manufacturing of briquettes and pellets from cotton stalk biomass has created entrepreneurship opportunities for promotion of rural based industries and employment generation to rural youths in cotton growing region.

Business opportunities in biomass briquette based cremations : Burning the dead human bodies in the open air and on a pyre made of wood is an ancient rite and commonly followed practice in Hinduism. Traditionally cremation is mainly performed by using fire wood. Cremation of a single person requires about 300 kg of fire wood which is equivalent of two fully grown trees that takes at least 15 years to grow. Electrical and diesel based crematoriums are also being used as an alternative to fire wood based cremations. The closed chamber design of these crematoriums does not allow performing traditional rituals like *mukhagni, kapalkriya*which are culturally considered essential for liberation of souls as per Hindu Shastra. Since the last rites of a loved one are understandably a very sentimental issue, these non-traditional electrical and diesel cremations are not much accepted by the society at large.

In order to provide an eco-friendly solution and to allow and to perform traditional Hindu rituals during cremations, ICAR-CIRCOT, have developed briquette based eco-friendly, efficient and rapid burning green crematorium as an alternative to traditional fire wood based cremation. Briquettes made from agricultural biomass like cotton stalk, sugarcane bagasse, groundnut & castor seed shells, rice husk and paddy straw etc. can be used as greener and renewable alternative for fire wood in cremation.

The ICAR-CIRCOT Green Crematorium consists of a compact trapezoidal shaped cage and a forced draft aeration system for supply of air for rapid initiation of fire and for enhanced combustion process. The forced air required for combustion during cremation process is supplied through single phase electric fan to an aeration chamber, which distributes air at the bottom and two-sides of cage through manifold pipes and subsequently to individual pipes having holes. By making the air available at the location where the briquettes are burned, the proportion of CO being generated is considerably lowered leading to significant reduction in pollution during cremation process. This crematorium also can be used without forced draft aeration system and fire wood can also be used in place of briquettes.

ICAR-CIRCOT Green crematorium has many advantages over the traditional fire wood cremation. It requires only 200 kg of biomass briquettes as against 300 kg of fire wood in traditional cremations. Traditional fire wood cremation requires around 5 of kerosene. However, ICAR-CIRCOT crematorium does not require kerosene.The cost of cremation with ICAR- CIRCOT Crematorium comes to Rs. 2500/- as against Rs. 5500 for traditional cremation. Around 55 per cent of cost savingper cremation can be attained making it economical and ecofriendly.

Nagpur Municipal Corporation in state of Maharashtra has already installed ICAR-CIRCOT Green Crematorium at Ambazarighat and many cremations have been done effectively using briquettes made from cotton stalk and other agro-residues. The Institute has given non-exclusive license for manufacturing of green crematorium to a Nagpur based entrepreneur. Many more such kind of enterprises can be established for manufacturing of green crematorium.

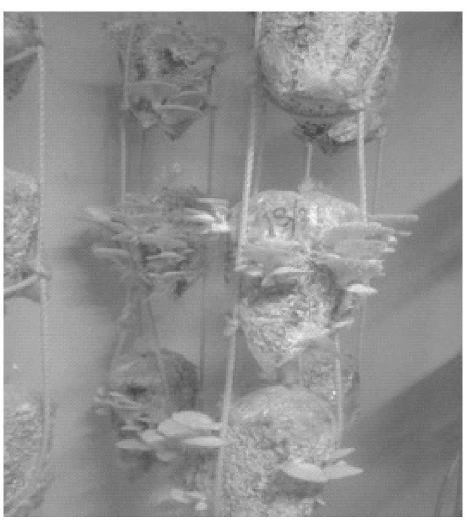
In India about 75 lakh cremations take place annually. Saving per cremation using ICAR-CIRCOT green cremation in comparison with cremation using firewood is Rs 3000/-, resulting in annual saving of Rs 2250 crores. Saving of 300 kg fire wood/cremation will save 22.5 lakh tonnes of fire wood *i.e.* 150 lakh trees per annum.The demand for 15 lakh tonnes of briquettes for cremation will create opportunities for establishment of around 300 additional briquetting plants (20 tonnes/day capacity) which in turn would result in additional employment opportunities to thousands of peoples in India. Thus the use of biomass briquettes for cremations has tremendous potential for creation of rural based industries and employment generation.

ICAR-CIRCOT Green Crematorium

On farm entrepreneurship through production of bio-enriched compost : Bio-enriched compost can be made out of cotton stalk using microbial consortia. An accelerated process has been developed by ICAR-CIRCOT for composting cotton stalk. Duration of composting is 45 days for wet and 60 days for dry cotton stalks. Yield of compost is 800 kg/tonne of cotton stalk. Accelerated process of composting saves 15 to 30 days of composting over farm yard manure (FYM). Bio-enriched compost made out of cotton stalks has higher NPK content (1.43:0.78:0.82) as compared to FYM (0.5:0.2:0.5). It results in saving of Rs. 9000 per ha by replacing FYM (12 tonne) with cotton stalk compost (5 tonne). It can be used for soil health enrichment as a substitute to chemical fertilizers. This technology is demonstrated through hands on training to farmers of Wardha, Nagpur and Amaravati District of Maharashtra and of Sirsa of Haryana and many famers has adopted it. Rural enterprises for production of compost from cotton stalk can be established at farm level in rural areas.

Compost from cotton stalk

Developing cottage industry for cultivation of Oyster mushroom using cotton stalk : ICAR-CIRCOT has established the suitability of cotton stalks for production potential (growth performance and yield) of oyster mushroom and developed the protocol for cultivation of oyster mushroom. Oyster mushroom (*Pleurotusflorida* and *Pleurotusostreatus*) can be cultivated on hot water treated cotton stalks of 3-4 cm length. The mushroom can be cultivated by hanging bag technique. About 300 g of fresh oyster mushroom could be harvested from one kg of dry cotton stalks. The cropping period for cultivation of oyster mushroom in cotton stalks is 30 days. An average of two harvests can be done per crop.



Oyster mushroom cultivation on cotton stalk

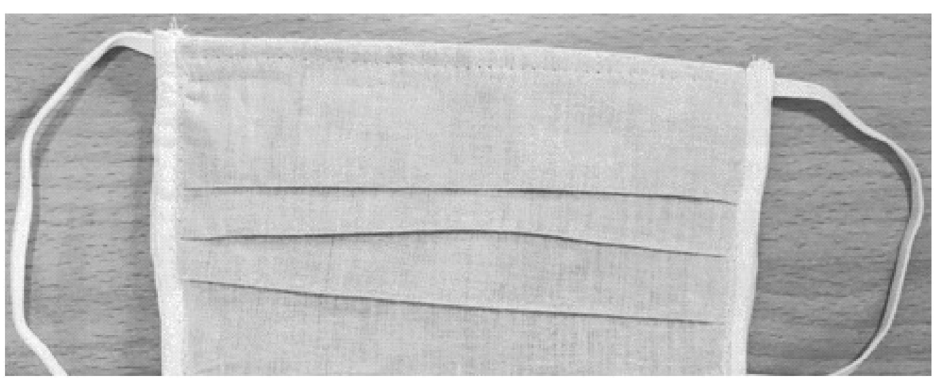
Harvested fresh mushroom

The average cost of production of one kg of fresh oyster mushroom is Rs. 50/- The selling price of fresh oyster mushroom in the market ranges from Rs. 80 to 150/-. Thus, a farmer can earn a minimum of Rs. 30/kg of oyster mushroom produced. On an average, a famer can generate a minimum additional income of Rs. 6,000/ac by cultivation of oyster mushroom in cotton stalks generated from an ac of land. Oyster mushroom cultivation using cotton stalk can be established as cottage industries in rural areas.

Business opportunities in production of particle board, composites and activated carbon ICAR-CIRCOT has developed technologies for preparation of particle boards, composites and activated carbon from cotton stalk. One tonne/ day capacity pilot plant for preparation of particle boards from cotton stalks has been established at Ginning Training Centre of ICAR-CIRCOT, Nagpur with the financial assistance from Common Fund for Commodities (CFC), Netherlands. The quality of the particle boards from cotton stalk is comparable to that of particle boards made from wood. These particle boards find applications in interior decoration, wall panelling, false ceiling, portioning, table tops etc. Cotton stalk has cellulosic materials which is

Cotton stalk particle boards

Cotton stalk composite trays for nursery



Face masks of activatated carbon from cotton stalk

useful as reinforcement for polymer composites. Cotton stalk/epoxy composites has better mechanical and good thermal resistance properties and hence can be used in thermal resistance roofing panels in construction fields and automotive sector. The cotton stalk based activated carbon has higher micro-porosity and meso-porosity and surface area around 1000 m^2/g. It can be used for the various applications such as air filtration, water purification, medical application and dye adsorption from textile effluents.Face masks using activated carbon made form cotton stalk has been developed for the traffic police. Business models needs to be established and promoted for production of particle boards and composites from cotton stalk.

Business Perspective in cotton by-product based industry : The biomass briquette and pellet industry has gained a rapid momentum over the past decade. The USA and most of European countries are the largest markets for biomass pellets. In Europe, pellets are mainly used for the production of electricity and residential heating. United Sates of America and Sweden procure about 4 and 13 per cent of their energy, respectively, from biomass and Sweden is implementing initiatives to phase out nuclear plants, reduce fossil-fuel energy utilization and enhance the use of bioenergy. Though, briquetting technologies are well developed and widely used commercially in developed countries, it is yet to receive a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming many operational problems associated with this technology are crucial factors in determining its commercial success.

In India, the briquette and pellet industry is gaining momentum in last few years. Over 250 small and large size pelleting plants are being operational in India. The growing number of entrepreneurs in the state of Maharashtra in India, it is evident that biomass briquetting and pelleting industry has emerged as a promising option for the new entrepreneurs and other users of biomass in India. It requires low investment and can generate employment among the rural masses leading to improvement in social as well as economic life of rural people. The utilization of cotton stalks and other agro-residues based briquettes and pellets is a step towards doubling the farmer's income. Further this business model needs to be strengthened so that more number of entrepreneurs will be benefitted. There is huge potential to establish profitable processingbusinesses in India based on cotton by-products, such as briquettes andpelletsas successful business models exist in our country. This business models would contribute to increased income opportunities for farmers and entrepreneurs, especially in rural areas, and to a more in cotton sector overall.Strategies to enhance farmer's income and create entrepreneurship and business opportunities in cotton sector must therefore include increased value addition to cotton by-products.

CROP IMPROVEMENT, BIOTECHNOLOGY AND POST HARVEST TECHNOLOGY

17

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Identification of cotton hybrids through PCR based molecular markers

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ABSTRACT : Parentage of F_1 hybrids of cotton *viz.*, Hybrid 4 (G-67 x American nectariless), G.Cot.Hy-6 (G.Cot.100 x G.Cot.10), G.Cot.Hy-8 (G.Cot.10 x Surat dwarf), G.Cot.Hy-10 (BC-68-2 x LRA-5166) and G.Cot.Hy-12 (G.Cot.16 x 76-IH-20) were verified using random amplified polymorphic DNA (RAPD), Inter simple sequence repeat (ISSR) and microsattelite (SSR) assays. Out of 84 primers surveyed, ten RAPD random primers (RPI1, RPI6, RPI7, RPI9, RPI11, RPI14, RPI17, RPI18, RPI22, and RPI24), two ISSRs (ISSR1 and ISSR9) and three SSR primers (SRT86, SRT91 and SRT97) were found to be polymorphic between parents of the hybrids studied. Further, two random decamers were found heteroallelic (RPI14 and RPI22). These highly informative primers not only differentiated the parent genotypes but also confirmed true F_1 hybrids. Primer RPI14 amplified two polymorphic loci designated as RPI14_350 (G.Cot.10) and RPI14_1000 (Surat dwarf) in G.Cot.Hy-8, while primer RPI22 amplified RPI22_1000 (G-67) and RPI22_700 (American nectariless) alleles in G.Cot.Hy-4, respectively. Markers *viz.*, RPI1, RPI6, RPI9, RPI11, RPI14, RPI17, RPI24, ISSR1, ISSR9, SRT86 and SRT97 produced female specific amplicons, while markers *viz.*, RPI7, RPI11, RPI14, RPI18, RPI22 and SRT91 produced male specific amplicons in the hybrids. Further, the combination of SRT86_620 and SRT91_580 marker can be used for identification of true hybrid, G.Cot.Hy-10. Our findings revealed that RAPD, ISSR and SSR markers are useful in parentage confirmation and true hybrid identification, further the markers identified would enhance efficiency of cotton breeding programs.

Key words : Cotton, ISSR, PCR, RAPD, SSR

Cotton is a natural fiber of vegetable origin and called **"White Gold"**, as it plays a vital role in trade, economy, industry, employment and foreign exchange earnings. India was the first country in the world to domesticate cotton for the production of cotton fabrics, when members of the Indus valley civilization began to grow the fiber in 1750 BC for manufacturing textiles (Thomasson, 2010). Cotton being often cross pollinated crop, the genetic purity of cotton hybrid seeds is adversely affected by the foreign pollen. Low genetic purity would cause seed suppliers a great loss from the planters' claim and could make it easy for a competitor to steal the inbred parent of a hybrid. Therefore, it is critical for seed suppliers to control seed genetic purity before marketing. Hence, in order to get better returns from the hybrids, greater seed purity and quality are emphasized. Traditionally, it has been the practice to carry out grow out test (GOT) to analyze the genetic purity of hybrid seeds using morphological traits. GOT involves growing a representative sample of the seed followed by analysis of several morphological and floral characteristics of the plant to determine true hybrid. Though morphological characterization does not require sophisticated laboratory techniques, the generation of data is time consuming, laborious, requires extensive use of land and the characters are liable to be influenced by a complex genotype and environment interaction. Hence, morphological differences between true hybrids and off types are not always apparent and cannot be recognised easily, especially when the parents are genetically similar. Alternatively, importance of biochemical markers such as isozymes and seed storage proteins through electrophoretic banding pattern was earlier reported in cotton for genetic purity determination (Kapse and Nerkar, 1985; Agarwal *et al.,* 1988). Nevertheless, the limitations of biochemical marker are: they require selection of a suitable isozyme and tissue type, failure to detect polymorphism in some closely related lines and sensitivity to environmental and experimental conditions. Hence, there is a need for more sensitive, reliable, quick, and accurate methods of characterization and cultivar identification for their effective utilization in breeding programme, granting Plant Variety Protection (PVP), certification, genetic resource management and more especially to assess the genetic purity of cotton hybrids.

With the advent of the molecular marker technology, it is now possible to test the purity of the hybrid seed immediately after harvesting and processing by DNA markers. Molecular markers not only allow the easy and reliable estimation of genetic diversity, identification of breeding lines, hybrids and cultivars but also facilitate the development of high density genetic linkage maps and marker assisted selection (Guo *et al.,* 2007; He *et al.,* 2007). The molecular marker technique *viz.*, RAPD, ISSR and SSR can be adopted for large scale screening and identification of true hybrids at early stages in cotton (Mehetre *et al.,* 2004; Dongre and Parkhi, 2005). The objective of the present study was to identify the true hybrids of cotton *viz.*, Hybrid-4, G.Cot.Hy-6, G.Cot.Hy-8, G.Cot.Hy-10 and G.Cot.Hy-12 and it's parents using PCR based markers *viz.*, RAPD, ISSR and SSR.

MATERIALS AND METHODS

Plant material and DNA extraction: Hybrid 4 (G-67 x American nectariless), G.Cot.Hy-6 (G.Cot.100 x G.Cot.10), G.Cot.Hy-8 (G.Cot.10 x Surat dwarf), G.Cot.Hy-10 (BC-68-2 x LRA-5166) and G.Cot.Hy-12 (G.Cot.16 x 76-IH-20) along with their parental lines were from our research station (MCRS, NAU, Surat). DNA was extracted from the five hybrids (F_1s) and respective parents by CTAB method (Murray and Thompson, 1980). The quality and quantity of DNA were estimated by measuring O.D. at 260/280nm in UV spectrophotometer. Intactness of genomic DNA was checked by gel electrophoresis.

PCR amplification and PCR program: A total of 25 RAPD primers, 19 ISSR primers and 40 microsatellite primers were surveyed across five hybrids (Hybrid 4, G.Cot.Hy-6, G.Cot.Hy-8, G.Cot.Hy-10, and G.Cot.Hy-12) and their respective parents. A 25 µL PCR reaction mixture contained 40 ng of genomic DNA, 1x PCR buffer, 200 µM of each dNTP, 1U Taq polymerase, 15 ng primer for RAPD and ISSR; and 15 ng each of forward and reverse primers for microsatellites. The DNA amplification was carried out in thermocycler. For RAPD analysis, an initial denaturing step of 6 min at 94Ú C was followed by 35 PCR cycles (denaturing at 94Ú C for 45 sec, primer annealing at 36Ú C for 1 min and primer extention at 72Ú C for 2 min). For ISSR analysis, an initial denaturing step of 10 min at 94Ú C was followed by 35 PCR cycles (denaturing at 94Ú C for 1 min, primer annealing at 49Ú C for 1 min and primer extension at 72Ú C for 2 min) and for microsatellite analysis, an initial denaturing step of 7 min at 94Ú C was followed by 30 PCR cycles (denaturing at 94Ú C for 45 sec, primer annealing at 55Ú C for 1 min and primer extension at 72Ú C for 2 min). A final step of 10 min at 72Ú C was carried out for polishing the ends of PCR products in all RAPD, ISSR and Microsatellite markers.

Gel electrophoresis: RAPD and ISSR products were electrophoresed on 1.2 per cent agarose gels, while SSR loci were resolved on 2.5 per cent agarose gels. Horizontal electrophoresis system was used and after electrophoresis, finely resolved PCR products were visualized under UV light and photographed.

RESULTS AND DISCUSSION

The assesment of genetic purity of hybrid using GOT has limitations and it warrants for faster, reliable and precise assesment of genetic make up of a genotype through molecular markers. In present study a total of 84 molecular markers comprising of 25 RAPD primers, 19 ISSR primers and 40 SSR primers were used for confirmation of five cotton F_1 hybrids *viz*., Hybrid-4 (G.67 x American nectariless), G.Cot.Hy-6 (G.Cot.100 x G.Cot.10), G.Cot.Hy-8 (G.Cot.10 x Surat dwarf), G.Cot.Hy-10 (BC-68-2 x LRA-5166), G.Cot.Hy-12 (G.Cot.16 x 76-IH-20). Out of 25 random decamers (RPI1 to RPI25), ten decamers *viz*., RPI1, RPI6, RPI7, RPI9, RPI11, RPI14, RPI17, RPI18, RPI22 and RPI24 showed polymorphism among the hybrids and their parents. Further, two random decamers were found heteroallelic (RPI14 and RPI22) and are highly informative primers not only differentiated the parent genotypes but also confirmed true F_1 hybrids. RPI14 has confirmed the true hybrid of G.Cot. Hy-8 by producing polymorphic fragments of 350bp length in female (RPI14_350, G.Cot.10) and male polymorphic loci with allele of 1000bp size (RPI14_1000, Surat dwarf). Similarly, RPI22 confirmed the true hybrid of Hybrid-4 by producing polymorphic amplicon of RPI22_1000 and RPI22_700 in female (G-67) and male parents (American nectariless) respectively. Thus, RPI14 and RPI22 independently, not only differentiated the parents but also confirmed parentage of F_1 hybrids *viz*., G.Cot.Hy-8 and Hybrid-4 respectively (Fig 1A and 1B). The RAPD primers that showed in male specific amplicons in different hybrids are RPI7_950 and RPI14_350 in Hybrid-4; RPI14_350, RPI18_1400 and RPI22_1000 in Hybrid-6; RPI11_2600 in Hybrid-8. Whereas, decamers *viz*., RPI6_540 in Hybrid-4; RPI11_2600 and ISSR9_620 in Hybrid-6; RPI6_540, and RPI17_1400 in Hybrid-8; RPI1_800, RPI9_350, and RPI14_350 in

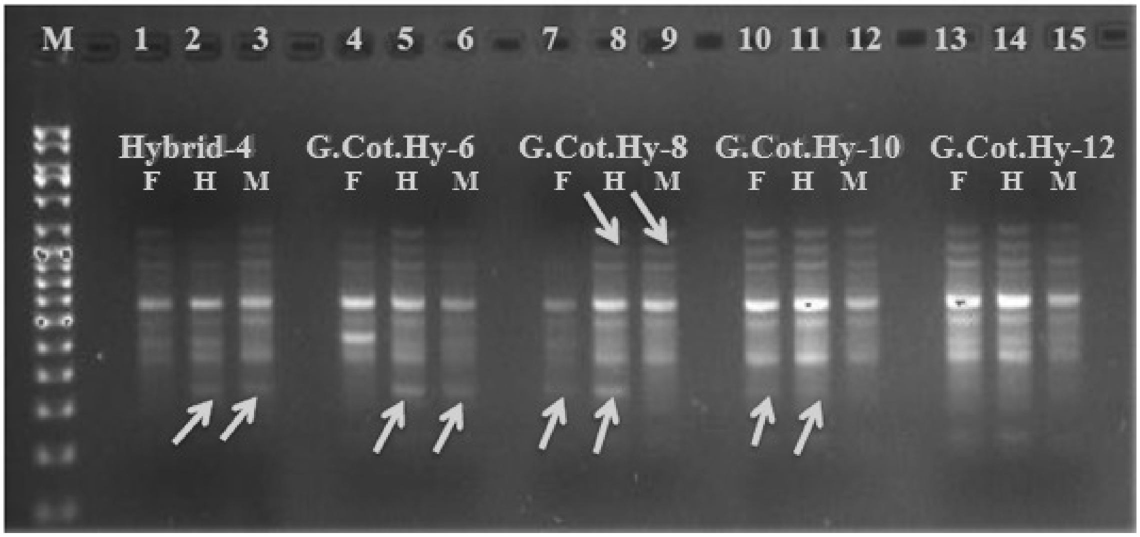

Fig. 1A. Primer RPI14 led to the confirmation of hybridity of G.Cot.Hy-8 in which 1000 bp band present in hybrid and male but absent in female. 350 band of same primer present in female and hybrid but absent in male.

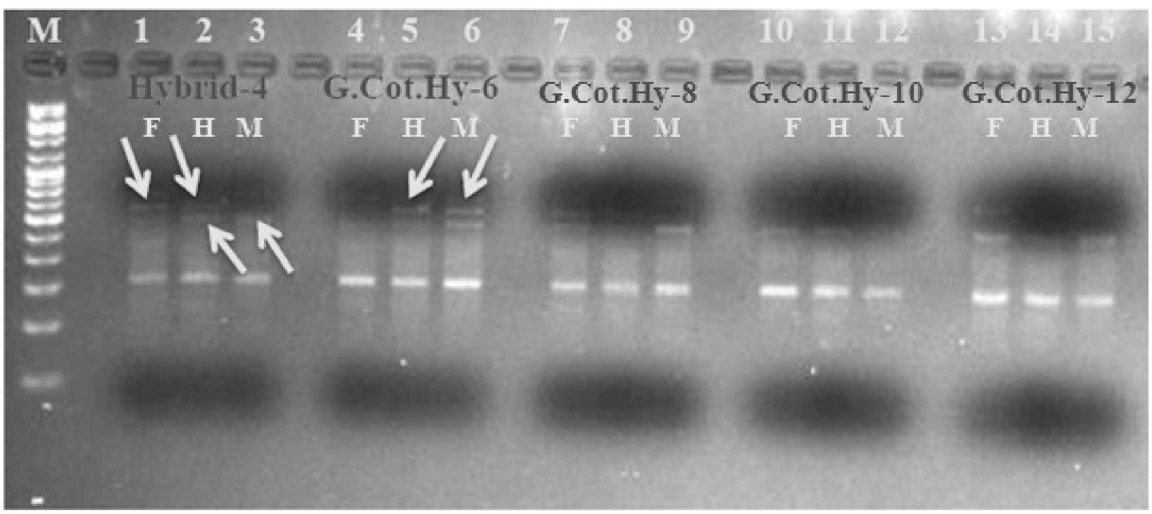

Fig. 1B. Primer RPI22 led to the confirmation of hybridity of G.Cot.Hy-4 in which 700 bp band present in hybrid and male but absent in female.1000 band of same primer present in female and hybrid but absent in male (In Figure 1A and 1B. **Lane 1 to 15:** L1- G.67; L2- Hybrid-4; L3- American nectariless; L 4-G.Cot.100; L5- G.Cot.Hy-6; L6-G.Cot.10; L7- G.Cot.10; L8- G.Cot.Hy-8; L9-Surat dwarf; L10- BC68-2; L11- G.Cot.Hy-10; L12- LRA-5166; L13- G.Cot.16; L14- G.Cot.Hy-12; L15- 6-IH-20, F-Female parent, H-Hybrid, M-Male parent)

Hybrid-10. RPI9_350 and RPI24_1180 in Hybrid-12 produced female specific amplicons. The RAPD markers produced unique banding pattern and not only discriminated cotton parents, but also identified their true hybrids. Therefore, RAPD technique became the most widely used molecular technique for genetic purity study, due to its technical simplicity and inexpensiveness.

Out of 19 ISSR assessed two primers ISSR1 and ISSR9 showed polymorphic amplification pattern. ISSR1 generated a female specific amplicon of 540 bp (ISSR1_540) in the G.Cot.Hy-12. ISSR9 has identified female specific amplicon of 620 bp (ISSR9_620) in the G.Cot.Hy-6 and 940 bp (ISSR9_940) in the G.Cot.Hy-10. As ISSR primers amplify DNA segment present at an amplifiable distance between two identical microsatellite repeat regions oriented in opposite direction. The polymorphism detected would be relatively more stable and repeatable. Thus, ISSRs (ISSR1 and ISSR9) can be used to identify female parent of the respective hybrid *viz.*, G.Cot.Hy-10 and G.Cot.Hy-12. Further, out of 40 SSR (9 SRT, 20 MGHES and 11 JESPER series) assessed three primers SRT86, SRT91 and SRT97 showed polymorphic amplification pattern. SRT86 generated one female specific amplicon of 620 bp (SRT86_620) and SRT91 generated male specific amplicon of 580 bp (SRT91_580) in G.Cot.Hy-10. SRT97 detected female specific amplicon of 350 bp (SRT97_350) in the G.Cot.Hy-12. The codominant nature of SSR marker with highly reproducible polymorphism makes it as a marker choice for the genetic purity studies. Thus, G.Cot.Hy-10 can be identified by SRT86_620 (female specific amplicon) and SRT91_580 (male specific amplicon) marker combination. Earlier Asif *et al.* (2009) identified the parentage of F1 hybrids of cotton (FH-883 and FH-631S) using RAPD (OPM07_800 and OPM07_925) and microsattelite assays. Dongre *et al* (2011) confirmed F1 hybrid Phule-388 and its parents using RAPD, ISSR and SSR markers. Two RAPD markers (OPA-08 and OPA-1); and two SSR markers (JESPER-151 and JESPER 152) were found useful to differentiate and parents and hybrid. The molecular markers used in the present study identify true hybrids and these markers would aid to speed up breeding processes in future.

CONCLUSION

The present study demonstrates that RAPD, ISSR and SSR banding pattern of the parents compared with their respective hybrids clearly recognize true hybrids in case of heteroallelic markers and even combination of makers can also be used to identify the true hybrids.

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G. Cot. Hy-12 (BG-II) - A high yielding hybrid for irrigated and rainfed ecosystem of Gujarat

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ABSTRACT : The hybrid G.Cot.Hy-12 (BG-II) was field tested at Surat, Junagadh and Talod in irrigated condition and at Bharuch and Dhandhuka in rainfed condition. Under irrigated condition G.Cot.Hy-12 (BG-II) gave significantly higher yield than its non *Bt* counterpart and 13.5 per cent higher yield as compared to RCH-2 (BG-II) in pooled analysis. In rainfed conditions, hybrid recorded 18.1 per cent increased yield over its non *Bt* counterpart and 6.0 per cent increased yield over RCH-2 (BG-II) in pooled analysis. Overall G.Cot.Hy-12 (BG-II) showed its superiority in yield (2115 kg/ha) over its non *Bt* counterpart by 46.6 per cent and RCH-2 (BG-II) by 11.1 per cent. Further, the mean *Cry1Ac* protein of 9.14 ug/g in leaf , 3.49 ug/g in square, 4.96 ug/g in boll; and *Cry2Ab* protein of 621.21 ug/g in leaf, 446.43 ug/g in square and 392.83 ug/g in boll was recorded. The hybrid had good boll size (4.4 g) with good opening and stay green character. It recorded staple length of 28.1 mm with good uniformity (47), average fineness (4.2 mv), medium fibre strength (21.7 g/tex) and good maturity (0.84) comparable to its non *Bt* counterpart. The performance of G.Cot.Hy-12 (BG-II) against all three intended bollworms was negligible and comparable to other *Bt* hybrids, while above ETL in non *Bt* counterpart. The hybrid showed below ETL population of major sucking pests similar to *Bt* hybrids and non *Bt* counterpart. It was found moderately resistant to bacterial leaf blight and *Alternaria* leaf spot disease and free from grey mildew. The hybrid was recommended for commercial cultivation in Gujarat state for rainfed and irrigated tracks by EBAM of GEAC, New Delhi.

Cotton aptly called **"White Gold"** as it plays a vital role in the economy of India. Cotton and its products account for 30 per cent in foreign exchange earnings and three per cent in GDP of the country. Gujarat has for long been in the forefront of cotton. Occupying nearly 30 per cent of the area, the state contributes nearly 35 per cent to the national cotton production. The last decade has witnessed unparallel growth of cotton in Gujarat ever recorded in the annals of agriculture. With a production of around 100 lakh bales annually and productivity revolving around 500-650 kg/ha.

G.Cot.Hy-12 was a popular hybrid with stay green characters before *Bt*s introduction. This versatile hybrid is medium duration, with comparatively big boll size, high yielding and tolerant to pest. Its specialty is to suited to irrigated and rainfed both situations. Its Non *Bt* (N*Bt*) version hybrid was released in 2005 under the aegis of All India Coordinated Cotton Improvement Project by Main Cotton Research Station, NAU, Surat and notified by Department of Agriculture and Cooperation, Government of India, vide no. SO 599 (E) dated 25th April 2006. Gujarat State Seed Corporation Limited – a leading seed company in public sector had been instrumental in commercializing the hybrid seed production technology and providing quality seeds to farmers at affordable price. The G.Cot.Hy-12 (BG-II) is a joint efforts of NAU and GSSC. The female parent was converted to BG-II background and the hybrid was developed using converted female parent and non *Bt* male parent.

MATERIALS AND METHOD

Experiment details : The G.Cot.Hy-12 (BG-II) was tested in irrigated condition at three locations *viz*., Surat, Junagadh and Talod and in rainfed condition at two locations *viz.,* Bharuch and Dhandhuka in *kharif* 2014. This hybrid along with its non *Bt* counterpart, RCH-2 (BG-II), G.Cot.Hy-6 (BG-II), G.Cot.Hy-8 (BG-II) G.Cot.Hy-8 N*Bt* were evaluated in RBD with three replications. Standard agronomic practices were followed to raise a good crop and data were recorded.

RESULTS AND DISCUSSION

Mean *Cry1Ac* and *Cry2Ab* (ug/g dry weight of tissue) contents in tissues of G.Cot.Hy-12 BG-II was estimated by Mahyco Monsanto Biotech (India) Ltd. and the values are given in the below table

MON15985 event was also confirmed by Mahyco Monsanto Biotech (India) in G.Cot.Hy-12 BG-II.

Table 1. Protein expression data

Tissue	*Cry1Ac*	*Cry2Ab*
Leaf	9.14	621.21
Square	3.49	446.43
Boll	4.96	392.83

The Bioefficacy study against *Spodoptera* and *Helicoverpa* was carried out at Main Cotton Research Station, NAU, Surat. The mortality of neonate larvae of *Spodoptera* was recorded 100 per cent in mature leaf and square whereas mortality of neonate larvae of *Helicoverpa* was recorded 100 per cent in mature leaf, square and boll.

Seed cotton yield (Table 2) : Under irrigated condition, G.Cot.Hy-12 (BG-II) gave significantly higher yield than its non *Bt* counterpart and 13.5 per cent higher yield as compared to RCH-2 (BG-II) in pooled analysis. In rainfed conditions, the hybrid recorded 18.1 per cent increased yield over its non *Bt* counterpart and 6.0 per cent increased yield over RCH-2 (BG-II) in pooled analysis.

Performance of G.Cot.Hy-12 (BG-II) across locations and situations clearly exhibited its significant superiority in yield over its non *Bt* counterpart and numerical superiority over RCH-2 (BG-II) with 11.1 per cent yield increase. The yield data indicated that hybrid is most suited for both irrigated as well as rainfed conditions and this is the special feature of the proposed hybrid.

Lint yield (Table: 3) : The lint yield of the G.Cot.Hy-12 (BG-II) was significantly higher

Table 2. Performance of G.Cot.Hy-12 (BG-II) for seed cotton yield at different locations

Sr. No	Entry	Seed cotton yield (kg/ha)									**Overall mean**	Per cent increase
		Irrigated condition					Rainfed condition					
		Surat	Junagadh	Talod	**Pooled Mean**	Per cent increase	Bharuch	Dhand-huka	**Pooled Mean**	Per cent increase		
1	G.Cot.Hy -12 (BG-II)	2784	1981	2466	**2410**		1368	1978	**1673**		**2115**	
2	G.Cot.Hy -12 Non *Bt* Counterpart	1447	1800	1130	**1459**	65.2	1005	1829	**1417**	18.1	**1442**	46.6
3	G.Cot.Hy-6 (BG-II)	2349	2212	2491	**2351**	2.5	1128	1906	**1517**	10.3	**2017**	4.8
4	G.Cot.Hy-8 (BG-II)	2378	2263	2259	**2300**	4.8	1292	1628	**1460**	14.6	**1964**	7.7
5	G.Cot.Hy-8 (NBT)	1405	2160	1966	**1844**	30.7	949	1726	**1338**	25.0	**1641**	28.9
6	RCH-2 (BG-II)	1905	1852	2611	**2123**	13.5	1195	1960	**1578**	6.0	**1905**	11.1
	CD (p=0.05)	355	448	540	**435**		328	NS	**439**		**438**	
	C.V (%)	10.1	13.4	15.1	**14.6**		12.6	17.7	**15.6**		**16.2**	

Table 3: Performance of G.Cot.Hy-12 (BG-II) for lint yield at different locations

Sr. No	Entry	Lint yield (kg/ha)									Overall mean	Per cent increase
		Irrigated condition					Rainfed condition					
		Surat	Junagadh	Talod	Pooled Mean	Per cent increase	Bharuch	Dhand-huka	Pooled Mean	Per cent increase		
1	G.Cot.Hy -12 (BG-II)	969	613	805	796		422	672	547		696	
2	G.Cot.Hy -12 Non *Bt* Counterpart	511	568	374	484	64.3	339	624	482	13.6	483	44.0
3	G.Cot.Hy-6 (BG-II)	803	737	844	795	0.1	350	557	454	20.6	658	5.7
4	G.Cot.Hy-8 (BG-II)	816	793	789	799	-0.4	418	489	454	20.6	661	5.3
5	G.Cot.Hy-8 (N*Bt*)	500	731	691	641	24.2	304	545	425	28.9	554	25.6
6	RCH-2 (BG-II)	644	621	886	717	11.0	361	553	457	19.7	613	13.5
	CD (p=0.05)	198	158	178	186		92	114	129		151	
	C.V (%)	12.5	14.3	15.4	14.9		9.6	10.0	12.5		16.5	

Table 4. Performance of G.Cot.Hy-12 (BG-II) for sucking pest incidence

Sr. No.	Hybrid	Average sucking pests/ 3 leaves								Mealy bug (Grade/plant)		Predators/ plant	
		Jassid		Aphid		Thrips		Whitefly					
		TV	OV	TV	OV	TV	OV	TV	OV	TV	OV	TV	OV
1	G.Cot.Hy-12 (BG-II)	2.25	4.6	1.45	2.00	2.27	4.7	2.29	4.8	0.75	0.70	0.93	0.40
2	G.Cot.Hy-12Non *Bt* Counterpart	2.26	4.8	3.67	13.3	2.33	5.0	3.15	9.5	0.79	0.13	0.98	0.47
3	G.Cot.Hy-6 (BG-II)	1.84	3.0	1.7	3.0	2.02	3.7	1.42	1.8	0.79	0.13	0.91	0.33
4	G.Cot.Hy-8 (BG-II)	1.84	3.0	1.45	2.0	1.83	2.9	2.28	4.7	0.83	0.20	0.84	0.20
5	G.Cot.Hy-8 (N*Bt*)	1.67	2.4	1.31	1.4	2.04	3.7	3.34	10.7	0.79	0.13	0.94	0.40
6	RCH-2 (BG-II)	2.77	7.3	2.95	8.3	2.66	6.7	2.41	5.30	1.19	0.93	1.02	0.53
	CD (p=0.05)	0.28		0.97		NS		0.64		0.17		NS	
	C.V (%)	13.51		29.26		15.40		15.24		11.08		13.44	

TV= Square root transformed value OV= Original value

Table 5. Performance of G.Cot.Hy-12 (BG-II) for incidence of bollworms

Sr.	Hybrid	Average boll worm damage (%)								Pink Boll worm damage (%)			
		Square Damage (%)		Green Boll Damage (%)		Open Boll Damage (%)		Locule Damage (%)		Open Boll Damage (%)		Locule Damage (%)	
		TV	OV	TV	OV	TV	OV	TV	OV	TV	OV	TV	OV
1	G.Cot.Hy -12 (BG-II)	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00
2	G.Cot.Hy -12Non *Bt* Counterpart	20.2	12.20	20.46	12.31	16.33	7.95	13.73	5.68	9.96	3.02	7.49	1.70
3	G.Cot.Hy-6 (BG-II)	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00
4	G.Cot.Hy-8 (BG-II)	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00	0.29	0.00
5	G.Cot.Hy-8 (N-*Bt*)	13.4	5.43	14.12	5.98	15.10	6.80	11.65	4.08	9.49	2.72	7.20	1.58
6	RCH-2 (BG-II)	1.95	0.28	0.29	0.00	6.44	1.26	4.55	0.63	6.44	1.26	4.55	0.63
	CD (p=0.05)	3.64		2.34		0.87		1.03		0.83		1.00	
	C.V (%)	30.80		19.90		7.16		10.32		10.15		15.26	

TV= Arcsine transformed value OV= Original value than its counterpart non *Bt* in irrigated condition, whereas it had registered 11.0 per cent increase over RCH-2 (BG-II). In rainfed condition, the hybrid gave 13.6 per cent and 19.7 per cent increased in lint yield as compared to non *Bt* counterpart and RCH-2 (BG-II), respectively.

In the mean lint yield across locations and situations, the hybrid recorded 44.0 per cent high and significant over its non *Bt* counterpart. When compared to RCH-2 (BG-II) the proposed hybrid recorded 13.5 per cent higher lint yield.

Yield contributing characters, economic characters and fiber quality parameters (Table 4) : The mean performance of G.Cot. Hy-12 (BG-II) for bolls per plant and boll weight was 29.5 and 4.4 g, respectively. The hybrid recorded on an average 33.4 per cent ginning outturn and 18.36 per cent oil content. In respect of fiber quality particularly for 2.5 per cent span length, the hybrid across five locations had recorded 28.1 mm which was similar to its non *Bt* counterpart and marginally less than RCH-2 (BG-II). However, category of medium staple (25.0 to 29.0 mm) is not changed for G.Cot.Hy-12 (BG-II) the as per DUS descriptor. The length uniformity ratio (LUR) of the hybrid was 47 and its non *Bt* counterpart was 48 and RCH-2 (BG-II) was 48 also. The fineness of the hybrid as well as its non *Bt* counterpart and RCH-2 (BG-II) was fell under medium category. The strength of the fibers of hybrid was 21.7 g/tex which was medium. The G.Cot.Hy-12 (BG-II), its non *Bt* counterpart as well as RCH-2 (BG-II) produced good mature fibre (0.84).

Incidence of sucking pests and borer (bollworm) pests: (Table 5 and 6) : The hybrid and its non *Bt* counterpart recorded below ETL populations of sucking pests, while RCH-2 (BG-II) recorded above ETL population of jassid. The hybrid G.Cot.Hy-12 (BG-II) showed parity with non *Bt* counterpart and both had recorded lower population of jassid and mealy bug compared to RCH-2 (BG-II). Aphid and whitefly population was below ETL in G.Cot.Hy-12 (BG-II) and in its non *Bt* counterpart as well as RCH-2 (BG-II). The population of thrips and predators showed non significant values amongst hybrid, its counter parts and other *Bt* hybrids.

No damage to square, green bolls, open bolls and locule was observed in the G.Cot.Hy-12 (BG-II) whereas RCH-2 (BG-II) showed very low level of square damage, open bolls damage and locule damage compared to non *Bt* counterpart.

Reaction against diseases (Table7) : G. Cot. Hy-12 (BG-II) showed moderately resistant reaction to bacterial blight and Alternaria leaf spot diseases. No grey mildew incidence recorded in any of the hybrids.

CONCLUSION

The non *Bt* hybrid G.Cot.Hy-12 which was released in 2005 under the aegis of AICRP on Cotton and notified by DAC, Ministry of Agriculture, Government of India vide No. SO 599 (E) dated 25th April 2006. The hybrid has capacity of stay green which reduce the trash content during picking besides this comparatively big boll size with good opening facilitate easy picking. G. Cot. Hy-12 (BG-II) recorded 13.5 per cent yield increase in irrigated condition, 6.0 per cent in rainfed condition and in overall performance it was observed upto 11.1

Table 6. Performance of G.Cot.Hy-12 (BG-II) for disease reaction

Sr. No.	Entry	Bacterial blight (PDI)			Maximum grade	Final reaction	Alteranria leaf spot (PDI)			Maximum grade	Final reaction
		August	September	October			October	November	December		
1	G.Cot.Hy -12 (BG-II)	5.33	6.17	4.33	2	Moderately resistant	0.00	0.00	2.00	2	Moderately resistant
2	G.Cot.Hy -12 Non *Bt* Counterpart	5.83	9.50	7.83	3	Moderately resistant	0.00	1.50	3.00	2	Moderately resistant
3	G.Cot.Hy-6 (BG-II)	0.83	1.83	2.50	1	resistant	0.00	1.50	9.50	3	Moderately susceptible
4	G.Cot.Hy-8 (BG-II)	3.17	6.50	8.00	2	Moderately resistant	0.00	1.00	6.00	2	Moderately resistant
5	G.Cot.Hy-8 (N*Bt*)	4.50	5.83	7.50	2	Moderately resistant	0.00	2.00	3.00	2	Moderately resistant
6	RCH-2 (BG-II)	3.67	6.17	8.50	2	Moderately resistant	0.00	1.50	3.00	2	Moderately resistant

Table 7. Mean performance of G.Cot.Hy-12 (BG-II) for yield attributing traits, economic characters and fiber quality parameters

Sr No.	Hybrid	Ginning outturn (%)	Bolls/ plant	Boll weight (g)	Oil content (%)	2.5 per cent span length (mm)	Fibre fineness (mv)	Fibre strength at 3.2 mm gauge (g/tex)	Maturity ratio	LUR
1	G.Cot.Hy-12 (BG-II)	33.4	29.5	4.4	18.36	28.1	4.2	21.7	0.84	47
2	G.Cot.Hy-12Non *Bt* Counterpart	33.5	22.7	3.9	17.55	28.1	4.3	22.1	0.84	48
3	G.Cot.Hy-6 (BG-II)	34.1	28.8	4.0	17.51	28.6	4.3	22.9	0.85	50
4	G.Cot.Hy-8 (BG-II)	34.8	30.5	3.7	17.82	26.8	4.3	21.1	0.83	48
5	G.Cot.Hy-8 (N*Bt*)	34.9	25.9	4.0	17.37	26.9	4.5	23.5	0.85	49
6	RCH-2 (BG-II)	34.3	31.4	3.9	17.06	29.2	4.3	21.0	0.84	48

per cent compare to RCH-2 (BG-II). The hybrid performed well both in irrigated and rainfed conditions. The hybrid yielded 4.8 per cent and 14.6 per cent higher seed cotton yield than G.Cot.Hy-8 (BG-II) under irrigated and rainfed situations, respectively. Further, 7.7 per cent higher seed cotton yield was depicted over G.Cot.Hy-8 (BG-II) across all the locations. Similarly, hybrid recorded 2.5 per cent and 10.3 per cent higher seed cotton yield as compared to G.Cot.Hy-6 (BG-II) under irrigated and rainfed conditions, respectively. Thus, the hybrid is an attractive choice for irrigated as well as rainfed conditions.

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Heterotic studies in diploid cotton (*Gossypium arboreum* L,) under rainfed conditions

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ABSTRACT : The investigation was undertaken to estimate heterosis with an objective of exploring possibilities of its commercial utilization under rainfed conditions. The experimental material comprised of 10 Crosses along with one standard hybrid check (PKV-Dh-1) and grown at Mahatma Phule Krishi Vidyapeeth, Oilseeds Research Station, Mamurabad Farm, Jalgaon in randomized block design with 2 replications. Observations were recorded for characters' namely seed cotton yield(kg/ha), bolls/plant, boll weight(g). The standard heterosis was calculated over standard hybrid check (PKV-Dh-1). Marked economic heterosis was observed for most of the characters studied. Among all the cross combinations the maximum heterosis for seed cotton yield of AKA-2004-29xJLA-794(50.43%), Highest heterosis for bolls/plant was observed in three crosses *viz*., AKA-7 X JLA-0614, JLA-1110 X JLA-505, and PA-402 X JLA-505 in the tune of 26.87%. for average boll weight AKA-2004-29 X JLA-794 (15.28%), The yield levels obtained in all the crosses and hybrid check are very low due adverse environment during the season, however the heterosis obtained are positive and highest as compare to check hybrid. The cross combination AKA-2004-29 x JLA-794 recorded highest and positive heterosis for seed cotton yield inspite of low number of bolls/plant, however this cross found superior for highest average boll weight and it reflected in high seed cotton yield and high heterosis for seed cotton yield and average boll weight and this cross combination may be use for further hybrid development programme. Wherever cross combination involving JLA-794 and JLA-0614 as a male parent, recorded significant positive heterosis for most of the yield contributing characters. Thus, the male parent JLA-794 and JLA-0614 may be used for exploitation of heterosis under rain fed conditions. There are several diploid hybrids and varieties under cultivation,this indicates there are much more scope of development of hybrids in diploid cotton and efforts are being taken through this study.

***Key wards** :* Bolls/plant,*Gossypium arboreum*, heterosis, seed cotton yield

The area under cotton crop is increasing day by day due to most remunerative cash crop. Other traditional crops like oilseeds, pulses, cereals are being replaced by cotton. It is mostly by *Bt* cotton hybrids. However desi(diploid) cotton varieties and hybrids are also maintaining its importance due to its low cost of cultivation and thrives well under rainfed situation. Moreover, marginal farmers are preferring the diploid cotton varieties and hybrids due to its inherent biotic and abiotic stress resistance characters.They are performing well under rainfed cultivation. Looking to the increasing trend of diploid cotton cultivation, work on development of diploid cotton hybrids are initiated at Oilseeds Research Station, Mamurabad farm, Jalgaon.

MATERIALS AND METHODS

Ten specific crosses were evaluated during Kharif 2017-2018 by using standard check hybrid PKV-Dh-1 under rainfed conditions. The experimental material grown at Mahatma Phule Krishi Vidyapeeth, Oilseeds Research Station, Mamurabad farm, Jalgaon in randomized block design with two replications under rainfed condition. Each hybrid was sown in one row in each replication with 20 dibbles/ row. The row length was 6.00 m. The spacing was 60 cm between rows and 30 cm between plant to plant.

Observations were recorded on seed cotton yield (kg/ha), bolls/plant and boll weight (g), The heterotic effect in terms of per cent increase or decrease over standard check (useful heterosis) were estimated for all the characters as per the standard procedure suggested by Rai(1978).

RESULTS AND DISCUSSION

Mean performance and heterosis over standard check hybrid PKV-Dh-1 for three characters is presented in Table: 1. The results indicated that the phenomenon of heterosis was of general occurrence; however, its magnitude varied with characters. The range of mean

Table 1: Per se performance and estimates of heterosis in *G.arboreum* Crosses.

Sr. No.	Name of the hybrids	Seed cotton yield (kg/ha)		Bolls/plant (No)		Avg. Boll Weight (g)	
		Mean	Heterosis	**Mean**	Heterosis	**Mean**	Heterosis
1	**2**	**3**	**5**	**9**	**11**	**12**	**14**
1.	AKA-2004-29 x JLA-794	**351***	50.43*	**7.2**	-36.11	**1.44***	15.28*
2.	AKA-7 x JLA-0614	**344***	49.42*	**13.4***	26.87*	**1.05**	-16.19
3.	JLA-1110 x JLA-0614	**294***	40.82*	**10.6**	7.55	**1.04**	-17.31
4.	AKA-7 x JLA-794	**234***	25.64*	**8.8**	-11.36	**0.95**	-28.42
5.	JLA-1110 x JLA-505	**252***	30.95*	**13.4***	26.87*	**1.06**	-15.09
6.	AKA-2004-29 x JLA-505	**285***	38.95*	**10.4**	5.77	**1.17**	-4.27
7.	PA-402 x JLA-505	**240***	27.50*	**13.4***	26.87*	**0.85**	-43.53
8.	JLA-1122 x JLA-505	**296***	41.22*	**9.8**	0.00	**1.14**	-7.02
9.	JLA-1122 x JLA-794	**261***	33.33*	**11.2**	12.50*	**1.09**	-11.93
10.	JLA-1122 x JLA-0614	**307***	43.32*	**11.2**	12.50*	**0.96**	-27.08
11.	PKV-Dh-1(check)	**174**	0.00	**9.8**	0.00	**1.22**	0.00
	Range	**174 to 351**	0.00 to 50.43	**8.8 to 13.4**	-36.11 to 26.87	**0.85 to 1.44**	-43.53 to 15.28
	SE +(kg/ha)	**31.91**	4.06	**0.57**	3.50	**0.045**	3.54
	C.D. (p=0.05)	**92.52**	11.45	**1.61**	9.89	**0.126**	10.01

Table 2. Trait specific promising crosses.

SN.	Name of the cross	Identified characters
1.	AKA-2004-29 X JLA-794	Seed cotton yield, boll weight (g)
2.	AKA-7 X JLA-0614	Seed cotton yield, bolls/ plant
3.	JLA-1122 X JLA-0614	Seed cotton yield, bolls/plant
4.	JLA-1110 X JLA-0614	Seed cotton yield, bolls/plant
5.	JLA-1122 X JLA-794	Seed cotton yield, bolls/plant

values among the cross combination for seed cotton yield varied from 174 kg/ha PKV-Dh-1 (Check) to 351 kg/ha (AKA-2004-29 x JLA-794). For bolls/plant highest was observed in three cross combinations in the tune of 13.4 bolls/plant while lowest was in cross(AKA-2004-29xJLA-794) (7.2 bolls/plant) Highest average boll weight 1.44 g per boll was observed in one cross combination (AKA-2004-29 x JLA-794) while lowest was in cross combinations PA-402 x JLA-505. (0.85 g/ boll) High magnitude of significantly positive heterosis over check hybrid was observed for seed cotton yield in all crosses However the crosses viz. AKA-2004-29 x JLA-794(50.43%) AKA-7 x JLA-0614 (49.42%), JLA-1122 x JLA-0614 (43.32%), JLA-1122 x JLA-505 (41.22%) showed positive and significantly high magnitude of heterosis among all crosses due to the diversity in the test hybrids these results are in agreement with the Kalsy *et al.,* (1992), Patel *et al.,* (2003) and Sonawane *et al.,* (2015)

For average bolls/plant mean range varies from 8.8 to 13.4.The significant highest positive heterosis for bolls/plant was found in three cross combination AKA-7 x JLA-0614, JLA-1110 x JLA-505 and PA-402 x JLA-505 in the tune of 26.387 per cent also other two crosses recorded significant positive heterosis for bolls /plant, most of them recorded significant high heterosis for seed cotton yield. and these are in agreement with the result reported by Amolic(1993),Kajjidoni and Patil (2003), Patel *et al.,* (2003) and Patil *et al.,* (2019).The mean value for average boll weight ranged from 0.85 to 1.44. Only one cross AKA-2004-29 x JLA-794 (15.28%) recorded positive heterosis for average boll weight. Jain (1996), Kumar *et al.,* (2003) and Sonawane *et al.,* (2015) have also recorded similar findings for these trait in *G. arboreum* hybrids. The yield levels obtained in all the crosses and hybrid check are very low due to adverse environment during the season, however the heterosis obtained are positive and highest as compare to check hybrid. The cross combination AKA-2004-29 x JLA-794 recorded highest and positive heterosis for seed cotton yield inspite of low bolls/plant, however this cross found superior for highest average boll weight and it reflected in high seed cotton yield and high heterosis for seed cotton yield and average boll weight and this cross combination may be use for further hybrid development programme. Wherever cross combination involving JLA-794 and JLA-0614 as a male parent, recorded significant positive heterosis for most of the yield contributing characters. Thus, the male parent JLA-794 and JLA-0614 may be used for exploitation of heterosis under rain fed conditions. There are several diploid hybrids and varieties under cultivation, this indicates there are much more scope of development of hybrids in diploid cotton

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Artle interspecific hybridization between *Gosspium hirsutum* and *Gossypium armourianum*: Morphological, cytological and molecular characterization of hybrids

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ABSTRACT : The triploid F_1 interspecific hybrids were synthesized between *Gossypium hirsutum* and the wild species G*ossypium armourianum*. The F_1 hybridity was confirmed by morphological, cytological and molecular marker approaches. The interspecific F_1 hybrids were triploid and male sterile. The female parents, MCU 5 and CO 14 had erect growth habit, cream petals, palmate leaves, green stem, thick and prominent leaf veins, embedded stigma, hairy stem and leaves, however, MCU5 with dense yellow anthers while CO 14 dense creamy anthers while the pollen parent *Gossypium armourianum* exhibited spreading growth habit, yellow petals, cordate leaves, reddish green stem, medium dense yellow anthers, thin leaf veins, protruded stigma and glabrous plant body. The growth habit, petal colour, leaf shape and size of interspecific F_1 hybrids were intermediate. Plant stem colour and hairiness, leaf pubescence, stigma protrusion and anther colour of *Gossypium armourianum* were observed to be dominant as hybrid fully resembled *Gossypium armourianum* for these characters. Petal spot was observed in *Gossypium armourianum* and in F_1 hybrids while petal spot was absent in MCU 5 and CO 14. Variable expression of petal spot, anther colour and filament colour was observed in the F_1 hybrids. The female parent MCU 5 and CO 14 had 52 chromosomes, *Gossypium armourianum* had 26 chromosomes and the interspecific F_1 was with 39 chromosomes. Significant differences were observed for pollen size, pollen fertility between parents and their hybrids. The F_1 interspecific hybrids had more than 97 per cent of sterile pollen grains. Out of 11 SSR markers which were polymorphic between parents, 5 markers unambiguously confirmed the hybrid status of interspecific hybrid. These hybrids may serve as useful genetic resource for the infusion of jassid resistance gene to *Gossypium hirsutum* cultivated genotypes.

Key words : Interspecific hybridization, insect resistance, triploid, wild *Gossypium* species

Cotton is a dicotyledon plant belonging to the Malvaceae family, genus G*ossypium* and is a highly diverse genus. This genus encompasses approximately 50 species including 45 diploids (2n = 2x = 26) and five allotetraploids (2n = 4x = 52) which are distributed throughout most tropical and subtropical regions of the World (Shim *et al.*, 2018). Among the four cultivated species, *Gossypium arboreum* and *Gossypium herbaceum* are diploids and *Gossypium hirsutum* and *Gossypium barbadense* are tetraploids. Diploid *Gossypium* species fall into eight cytological groups designated as A, B, C, D, E, F, G, and K based on their chromosomal pairing relationships and geographical distribution (Wendel and Grover, 2015). *Gossypium hirsutum* , also known as American cotton, is the most widely grown cotton species which is responsible for approximately 90 per cent of the total cotton production Worldwide. The *Gossypium armourianum* , one of 13 wild diploid D genome species, reportedly possesses resistance to jassid (Pushpam and Raveendran, 2006), pink bollworm (Brazzel *et al.*, 1956) and white flies. Wild *Gossypium* species possess massive amount unexplored genetic diversity that can be exploited to broaden the genetic base of cotton (Shim *et al.*, 2018). In the present study, crosses were effected between *Gossypium hirsutum* and *Gossypium armourianum* to transfer the characters for insect resistance due to D_2 smoothness trait and the caducous bract trait that could reduce the trace content of harvested seed cotton to *Gossypium hirsutum* (Manickam *et al.*, 2014). The F_1 hybrids and the parents were analysed to discriminate true hybrids using molecular markers (SSR) in conjuction with morphological and cytological analysis.

MATERIALS AND METHODS

The crossing block was raised during Winter 2017 season comprising of two *Gossypium hirsutum* pistil parents viz MCU 5 and CO 14 with AD1genome. The pollen parent, *Gossypium armourianum* having D genome was maintained in cotton wild species garden. Crosses were effected employing Doak’s method of emasculation and pollination and the set seeds were collected. The two F_1 interspecific hybrids along with their respective female parents *viz.,* MCU 5 and CO 14 were raised during Winter 2018. The male parent *Gossypium armourianum* being maintained in cotton wild species garden was used for recording data on various morphological, cytological traits and for molecular marker analysis. In order to confirm the hybridity status of the F_1 hybrids, 19 morphological characters *viz.,* growth habit, stem colour, stem pubescence, petiole colour, leaf shape, leaf colour, leaf incision, leaf veins, leaf texture, leaf hairiness, bract size, corolla colour, petal size, petal spot, anther colour, anther density, filament colour, position of stigma and nectar glands were observed on both the parents and the F_1 hybrids. Biometrical traits for 14 biometrical traits namely bracterial teeth number, bracterial length, bracterial breadth, petiole length, leaf length, leaf breadth, leaf area, pedicel length, petal length, petal breadth, pollen size diameter, pollen fertility (%), length of pistil and gossypol gland density were observed on both the parents and F_1 hybrids in order to confirm the hybridity status.

The fourth fully matured and expanded leaf from the top of the plant was taken and its maximum length and breadth was recorded. Leaf area was measured from 5 fully expanded, matured leaves of both parents and F_1 hybrids using leaf area meter and averaged. Flowers were collected in morning on the day of anthesis between 10.00 am to 11.00 am for pollen fertility study. Pollen fertility was recorded by dusting pollen grains in 1 per cent KI solution and viewed under a compound microscope. Only large, darkly stained and circular pollen grains were considered as fertile. In both parents and F_1 hybrids, four microscopic fields were taken to find out the pollen fertility percentage and averaged.

The mitotic metaphase chromosome study was carried out by using root tips to confirm the ploidy level of F_1 hybrids and their parents. Seeds of parents and their F_1 hybrids were soaked overnight and germinated in the germination paper. The roots were collected from the germinated seeds which are of 2-3 cm length in quick succession between 9.00 am to 10.00 am on bright sunny days and pretreated in para dichloro benzene to accumulate metaphase cells. After 2 hours, the pretreated root tips were washed thoroughly in running tap water and fixed in the ethanol: glacial acetic acid (3:1) fixative. Then, the root tips were kept under low temperature (4° C) for a period of four hours and root tips were thoroughly washed in distilled water and stored in 70 % ethanol. The roots were hydrolysed at 60° C for 5 min and washed thoroughly. Then, the root tips were treated in a 0.25 per cent pectinase solution for 15 min. in dark and put it in basic fuchsin stain for 30 min. in dark. The darkly stained extreme tip portion of the roots were excised out and the remaining portion was tear open in a drop of 1 per cent acetocarmine. The slide was covered with cover slip and heated gently over a sprit lamp. The excess stain was removed by giving gentle press with thumb between two layers of filter paper. The slide was temporarily sealed using wax and observed under the Olympus system microscope @ 1000X magnification. The chromosomes were counted from the metaphase cells and recorded pictorially.

Genomic DNA was isolated from three parents and their respective F_1 hybrids by the procedure suggested by Zhang and Stewart (2000). The isolated DNA was quantified using Nano Drop™ 1000 spectrophotometer. DNA was amplified using 2X PCR master mix (8µL), 0.66 mM forward (1.0 µL) and reverse (1.0µL) primers, 70 ng DNA template (1µL) and deionised water (4µL) in a 15µL reaction mixture. After PCR amplification, amplified products were resolved using 3 per cent agarose gel. The gels were viewed by UV illumination and documented using gel documentation system (Gel Doc™XR + Gel documentation system). A total of 20 SSR markers with high PIC value were selected and obtained from cotton marker database (CMD) (http://www.cottonmarker.org/) and were commercially synthesized and procured from Sai Scientific Company, Coimbatore. 2X PCR Master mixes were purchased from Bengaluru GeNei Ltd., Bengaluru, India.

RESULTS AND DISCUSSION

Morphological characters of pistil parents (MCU 5, CO 14) and pollen parent (*Gossypium armourianum*) and their F_1 hybrids were compared . Interspecific F_1 hybrids showed either dominance or intermediate expression for various morphological traits, growth habit, leaf shape, leaf size, leaf incision and petal colour of interspecific hybrid was found to be intermediate. Parents MCU 5 and CO 14 had deep leaf incision and *Gossypium armourianum* had no leaf incision, whereas, the F_1 hybrids had shallow leaf incision. Leaf shape of MCU 5 and CO 14 was palmate with 3-4 lobes, whereas, *Gossypium armourianum* had cordate leaves. In case of F_1 hybrid, leaves were palmate with 3-4 lobes and reduced in size as compared to *Gossypium hirsutum* leaves. The results are in agreement with Pushpam and Raveendran (2006); Harpreet Kaur *et al.*, (2016) where they have reported intermediate leaf shape and size in hybrids between *Gossypium hirsutum* and *Gossypium armourianum*. Similar intermediate expression of plant growth habit, leaf size and petal colour were reported in other interspecific hybrids such as between *Gossypium davidsonii* x *Gossypium anomalum*, *Gossypium arboreum* x *Gossypium thurberi, Gossypium hirsutum* x *Gossypium arboreum* (Ahmad *et al.*, 2011; Tahir *et al.*, 2011) and *Gossypium herbaceum* x *Gossypium australe* (Liu *et al.*, 2015). However, some workers have reported dominance for these characters. For example, *Gossypium hirsutum* x *Gossypium raimondii* triploid hybrid resembled the paternal parent in growth habit (Saravanan *et al.*, 2007). In this study, plant stem colouration and hairiness, leaf pubescence, position of stigma, anther colour of *Gossypium armourianum* were found to be dominant as hybrid fully resembled the male parent for these characters. Average pollen fertility was recorded to be 92.55, 93.83, 97.22 and 0.3 - 1.09 per cent in MCU 5, CO 14, *Gossypium armourianum* and F_1 hybrids respectively (Plate 4). Pollen fertility of parents and hybrids showed significant difference. Pushpum and Raveendran (2006) reported 9.04 % average pollen fertility in *Gossypium hirsutum* x *Gossypium armourianum* hybrid and 9.67 per cent in *Gossypium hirsutum* x *Gossypium raimondii* hybrids. About 2.19 per cent average pollen fertility was recorded by Harpreet Kaur *et al.*, (2016) in *Gossypium hirsutum* x *Gossypium armourianum* hybrids. The average pollen size of MCU 5, CO 14, *Gossypium armourianum* and F_1 hybrid were determined as 39.51, 39.93, 34.34 and 21.37 - 25.29 micrometer respectively (100X). Pollen size of F_1 hybrids showed more variation compared to parents. Significant differences were observed between the pollen sizes of the parents as well as between the parents and their hybrids.

Petal spot was not observed in *Gossypium hirsutum cv.,* MCU 5 and CO 14 while it was found in *Gossypium armourianum*. The F_1 hybrids of MCU 5 x *Gossypium armourianum* and CO 14 x *Gossypium armourianum* exhibited variation for petal spot size and intensity in different flowers of the same plant. It ranged from complete absence to dark pink colour with full size as that of male parent. Similar results were obtained by Harpreet Kaur *et al.*, (2016) in *Gossypium hirsutum cv.* F 1861 x *Gossypium armourianum*. However, complete dominance of petal spot in intra *hirsutum* crosses involving wild type x mutant strains were reported by Ahuja and Dhayal (2007). Tahir *et al.*, (2011) and Ahmad *et al.*, (2011) have reported reduction in the colour intensity of petal spot in F_1 hybrids in case of *Gossypium hirsutum* x *Gossypium arboreum* cross. Intermediate expression of filament colour was observed in the F_1 hybrid. Similar results were reported by Harpreet Kaur *et al.*, (2016) in the F_1 hybrids of *Gossypium hirsutum cv.* F 1861 x *Gossypium armourianum*. Filament colour of both the parents were colourless. But in case of F_1 hybrid, filament was either coloured or colourless in different flower bud and even within same plant, both coloured and colourless filaments were also observed.

Harpreet Kaur *et al.*, (2016) also observed similar results in *Gossypium hirsutum cv.* F 1861 x *Gossypium armourianum*. The portion that connects the filament and the anther was coloured in male parent and colourless in female parent, whereas both coloured and colourless connectives were observed in the same flower and different flowers of the same plant in the F_1 hybrids. Authors viewed that the variation observed in morphological traits of the F_1 hybrid between *Gossypium hirsutum cv.* F 1861 and *Gossypium armourianum* may be due to "Epigenetics". Rapp and Wendel (2005) described epigenetics as the alteration of phenotypes, without change in their coding sequence of the gene or the upstream promoter region. In beginning, allopolyploids are reported to be associated with variation and instability in phenotypes that cannot be accounted for by conventional Mendelian transmission genetics or chromosomal aberrations (Comai, 2000). Many causes including increased variation in dosage regulated gene expression, altered regulatory interactions, and rapid genetics and epigenetics changes which are probably conferred by genome wide interactions (Osborn *et al.*, 2003) have been suggested for such altered expressions.

Biometrical characters of parents and F_1 hybrids were compared and leaf area and petiole length of interspecific F_1 hybrid were found to be intermediate. Parents MCU 5, CO 14 and *Gossypium armourianum* had the leaf area of 154.85 cm^2, 157.73 cm^2 and 7.09 cm^2 respectively, whereas, the leaf area of F_1 hybrids MCU 5 x *Gossypium armourianum* and CO 14 x *Gossypium armourianum* were 36.62 cm^2 and 49.84 cm^2 respectively which are intermediate between both the parents, but mostly skewed towards the pollen parent owing to much reduction in lamina. Petiole length of MCU 5 and *Gossypium armourianum* was 11.75 cm and 1.28 cm respectively where as the F_1 hybrid exhibits the intermediate length of 5.44 cm. Petiole length CO 14 and *Gossypium hirsutum* was 12.21 cm and 1.28 cm respectively, whereas, the F_1 exhibits the intermediate length of 5.8 cm. Mitotic metaphase counts revealed that the presence of 52 chomosomes in *Gossypium hirsutum cv.* MCU 5 and CO 14, 26 chromosomes in *Gossypium armourianum*, 39 chromosomes in corresponding F_1 hybrids and confirmed the triploid status of the F_1 hybrids developed from cross between MCU 5 x *Gossypium armourianum* and CO 14 x *Gossypium armourianum.*

The female parents (MCU 5 and CO 14), male parent (*Gossypium armourianum*) and F_1 hybrids (MCU 5 x *Gossypium armourianum* and CO 14 x *Gossypium armourianum*) were subjected to polymorphic analysis using 20 cotton specific SSR markers for F_1 hybridy confirmation. SSR markers namely BNL 3948, BNL 3955, BNL 2443, CIR 407 and CIR 413 confirmed the hybridity status of interspecific hybrid revealing polymorphic bands from both the parents.

The present study revealed that the hybridity status of F_1 hybrids developed from cross between MCU 5 x *Gossypium armourianum* and CO 14 x *Gossypium armourianum* using morphological, cytological and molecular marker analysis. These F_1 hybrids are important genetic resources for cotton breeders to develop pest and disease resistant cultivars. These materials can be used as bridges for the transfer of pest and disease resistant genes from the wild species to cultivated varieties.

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Breeding for ultra low gossypol cotton seed (ULGCS)

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ABSTRACT : Cotton is used as dual purpose crop for fiber as well as for oil. There is considerable amount of variation for oil exists in diploids (12-24 per cent) and tetraploid (13-33 per cent). In general Gossypium species is considered to posses 21 per cent of oil. Cotton seed oil contains 50 per cent of linoleic acid (poly unsaturated fatty acid) which is ideal for human consumption. Every one kg of fibre is obtained from 1.65 kg of seed cotton. By considering the amount of protein present in the seed (23 per cent), global seed cotton yield of 47 million tons could serve as 10.8 million tons of protein, which is more than sufficient to cater the needs of daily protein requirement (50g/day) of nearly 590 million people per year. There is only one impediment in achieving this nutritional security is the "Gossypol". Gossypol is terpenoid aldehyde compound present in the entire plant parts of *Gossypium* species including seed. This imposes serious health problems in monogastric animals including human and impairs protein conversion ratio in ruminants. This warrants a need for developing, gossypol less seed cotton, which comes with premonition of herbivore attack to the plant parts, as gossypol deters most of the herbivore attack. An ideotype concept of glanded plants with glandless seed would be an ideal plant tailoring concept for breeding gossypol less seeds. Effective breeding approaches include (i) use of naturally available glandless mutants (ii) gene introgression from wild species namely *G.australe, G.bickii* and *G.sturtianum.* (iii) RNA interference (RNAi) approach which targets cadinene synthase for knock down of gossypol production with help of tissue specific promoters to express in seeds only. With this approach, gossypol content is reduced from 10000 ppm to less than 300 ppm, as much below the permissible limits by FAO (600 ppm). All these approaches we could easily achieve the edible oil production and nutritional security especially in India.

Key words : Cotton, gossypol, ultra low gossypol cotton seeds and oil

Cotton belongs to the genus of gossypium which comes under the family of Malvaceae. It consists of 45-50 species, with 40-45 being diploids and five being allotetraploids . The species are segregated into eight genome groups, labeled as A through G and K, on the basis of chromosome pairing affinities. In case of tetraploid, there are five species, designated $(AD)_1$ through $(AD)_5$ for their genome constitutions. Epidermal cellular outgrowth of seed is used as fibre for commercial purpose.

In India, cotton is cultivated in area of 12.2 mha with production of 36.1 million balles (Annual Report, AICRP on Cotton, 2019). India ranks first in global cotton area as well as production. Cotton is used as dual purpose crop for fiber as well as for oil. In general *Gossypium* species is having 21 per cent of oil in general; however, there is considerable amount of variation for oil exists in diploids (12-24 per cent) and tetraploid (13-33 per cent). Cotton seed oil possesses 50 per cent of linoleic acid (poly unsaturated fatty acid) which is ideal for human consumption. Every one kg of fibre is obtained from 1.65 kg of seed cotton. By considering the amount of protein present in the seed (23 per cent), global seed cotton yield of 47 million tons could serve as 10.8 million tons of protein, which is more than sufficient to cater the needs of daily protein requirement of 50g/day to nearly 590 million people per year.

Cottonseed oil is ranked one among the most unsaturated fatty acid containing oils, others being soybean, rapeseed, safflower, corn, and sunflower seed oils. It has a ratio of 2: 1 of polyunsaturated to saturated fatty acids and generally consists of 65-70 per cent unsaturated fatty acids including 18-24 per cent monounsaturated (oleic) and 42-52 per cent polyunsaturated (linoleic) and 26-35 per cent saturated (palmitic and stearic).

Cottonseed contains various terpenoid compounds namely gossypol (yellow), gossycaerulin (blue), gossyfulivin (orange), gossypurpurin (purple) and gossyverdurin (green). The gossypol founds to be higher in raw material than in cooked cottonseed, where as gossypupurin and gossyfulvin are found in higher proportion in cooked seed. These terpenoid compounds are associated with glandular secretary glands namely gosspoyl glands which presented in all the plant parts to give protection towards herbivore attack.

Gossypol affects the lung and heart functions of the non ruminant animals including human. In case of ruminate animals, gossypol binds with lysine and it affects the protein conversion ratio. In case of oil extraction, gossypol gives undesirable color to the oil and reacts with its protein and reduces its nutritive values.

By considering the above facts, it's desirable to breed genotypes which are having less gossypol content. This warrants a need for developing, gossypol less seed cotton, which comes with premonition of herbivore attack to the plant parts, as gossypol deters most of the herbivore attack. An ideotype concept of glanded plants with glandless seed would be an ideal plant tailoring concept for breeding gossypol less seeds. Effective breeding approaches include (i) use of naturally available glandless mutants (ii) gene introgression from wild species namely *G.australe, G.bickii* and *G.sturtianum*. (iii) RNA interference (RNAi) approach which targets cadinene synthase for knock down of gossypol production with help of tissue specific promoters to express in seeds only.

(i) Glandless mutants : A complete glandless plant was first identified by McMichael (1954). The gossypol content of cotton (*Gossypium* spp.) is controlled by at least six independent loci, namely gl_1, gl_2, gl_3, gl_4, gl_5 and gl_6. The formation of gossypol glands in the *G.hirstum* is controlled by two main alleles GI_2 and GI_3 located on the homoeologous chromosomes 12 (A genome) and 26 (D genome), respectively. Seed gossypol content is determined mainly by the GI_2 allele (Pauly 1979; McCarty *et al.,* 1996).

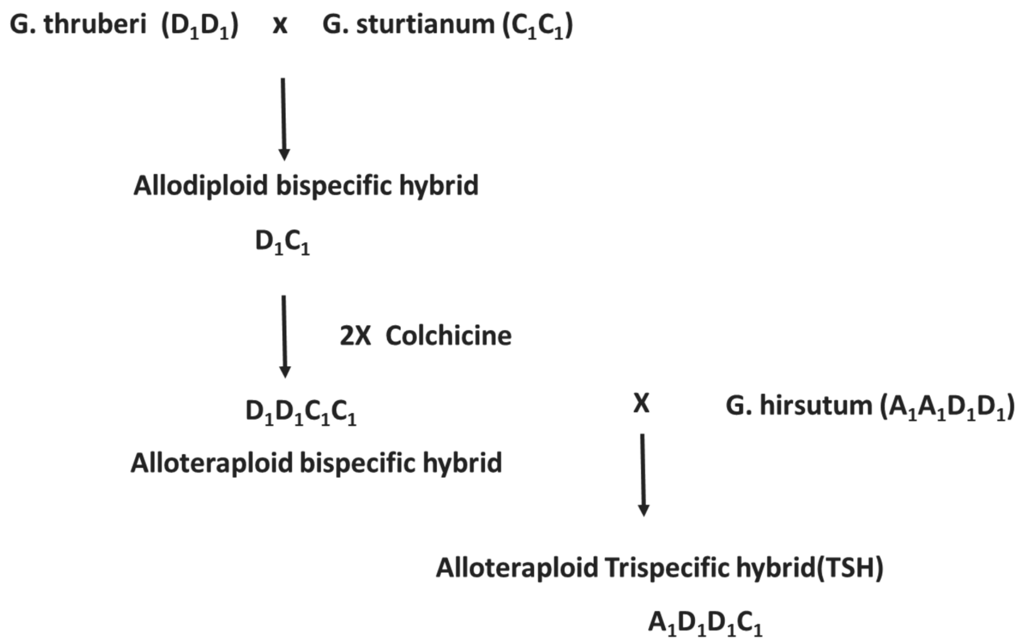

Fig. 1. Trispecific hybrid using *G.thurberi* as bridge species in *Thurberi-Sturtianum- Hirsutum* (TSH)

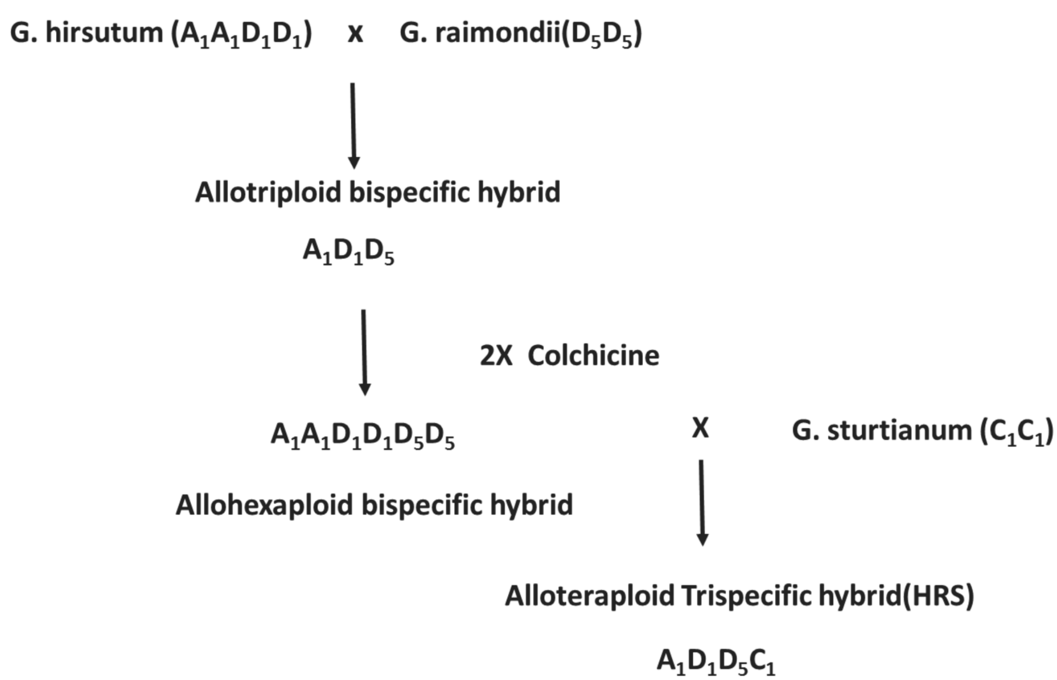

Fig.2. Trispecific hybrid using *G.raimondii* as bridge species in *Hirsutum Raimondii Strutianum* (HRS)

(ii) Gene introgression from wild species : Among the Gossypium species, only the species belongs to Australian continent namely *G. sturtianum, G.bickii* and *G.australe* possess the glandless seed and glanded-plant. Crossing of these Australian wild species *G.sturtianum* (C), *G.bickii* (G) and *G.australe* (G) with *G.hirsutum* (AD) is very difficult due to difference in genomic composition and chromosome dissimilarities. Bridge species helps in pairing between these genotypes. Crossing involves three species leads to trispecific hybrid production. *G. thruberi* is used as bridge species in production of Thurberi-Sturtianum-Hirsutum(TSH) hybrid (Fig 1) and *G.raimondii* in *Hirsutum Raimondii Strutianum* (HRS) hybrid (Fig 2).

The main difference between the trispecific hybrids (i) difference in bridge species (*G. thurberi* in TSH and *G. raimondii* in HRS), (ii) ploidy level in the final the crossing schemes: two tetraploid genotypes were crossed (4x x 4x) to obtain TSH, while HRS was derived from a cross between a hexaploid and a diploid genotype (6x x 2x). Homoeologous chromosomes of different species of *Gossypium* genomes rarely pair. These crossing schemes developed based on: (i) the translocations that occurred between A, C and D during Gossypium species divergence; (ii) the higher pairing affinity of the donor C chromosomes (large size) for A chromosomes (medium size) than for D chromosomes (small size) (iii) higher efficiency of the seed gossypol gland repression mechanism in the wild Australian genome against the A genome than the D genome (Mergeai *et al.,* 1995).

(iii) RNA interference (RNAi) approach : Traditional method of breeding using wild relative's takes long cycle and lots of aneupolid pairing problems leads to unviable hybrid formation. Achieving such an ideal plant is a long time goal. Here the molecular based approach helps in developing cotton gossypol less cotton seeds.

Gossypol is sesquiterpenoid aldehyde synthesized in Mevalonate (MVA) pathway, FPP ((2E,6E) farnesyl diphosphate) is converted into ä-cadinene by (ä)-cadinene synthase enzyme this is the first committed step in gossypol biosynthesis. This ä-cadinene is consequently hydroxylated at the C-8 position leading to 8-hydroxy-ä-cadinene. Through many uncharacterized steps, 8-hydroxy-ä-cadinene is converted to desoxyhemigossypol, which is a branching point leading to both gossypol and methylated gossypol (Benedict *et al.,* 2004).

Using RAN interference (RNAi) approach, delta-cadinene synthase (*dcs*) gene is targeted for repression of ä-cadinene synthesis. This repression has to be targeted only cotyledon to get gossypol less seeds. A seed specific promoter á globulin is used for RNAi to target cotyledon. DNA sequences containing inverted repeat nucleotide sequences of the delta-cadinene synthase (*dcs*) gene under the control of a seed specific promoter -globulin, which produces double-stranded ribonucleic acid (dsRNA) transcripts that trigger RNA-mediated silencing mechanism. The *dcs* gene encodes the delta-cadinene synthase (*dcs*) protein, the enzyme that catalyzes the cyclization of farnesyl diphosphate to delta-cadinene in the synthesis of gossypol and related terpenoids. Gossypol levels reduced from 10,000 ppm to 300 ppm, which is well below considered safe for human consumption by FDA (450 ppm) and FAO/WHO (600 ppm). Such a low level gossypol is called as ultralow gossypol. Rathore *et al.,* 2012 successfully developed a line *viz.,* TAM66274 using this RNAi technology.

As global population increases tremendously, feeding them is crucial and it has to be taken care in both way quantity and quality of foods. As world seriously suffers from malnutrition, it is vital to produce nutritious food. In such way, cotton is being used as fibre and oil crop, the proper removal of gossypol ascertains the protein requirement of world population. Apart from traditional plant breeding, the modern genomic technologies like CRISPR/Cas9 and RNAi shows promising way to tailor the plant expression pattern. In future, Cotton will serve as fiber, food, and oil simultaneously, which aids in solving the problem of world's food and nutritional security.

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Acceptability of drudgery reducing technologies in cotton picking

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ABSTRACT : Rural women in Haryana are involved in most of the agricultural operations, *viz.,* transplanting, weeding, harvesting and post-harvest activities like picking and plucking. Cotton picking is a tedious job exclusively handled by women folk in Haryana. A study was conducted on 200 rural women working at cotton fields in four villages, *viz.,* Kirtan, Ladwa, Talwandi Rana and Sadalpur of Hisar district and four villages *viz.,* Ukhalchana kot, Sikanderpur, Bajitpur and Jondhi of Jhajjar district in Haryana. Schedule was developed to collect data on socio-economic profile of the respondents. Cotton picking bag developed by College of Home Science, CCS Haryana Agricutlural University, Hisar was tested on all the 200 women undergoing one hour of cotton picking activity. During the study, time and activity profile, work output and acceptability of the cot bag was assessed. Women performed cotton picking activity between 50-60 days in a year. The women reported very severe pain in palm, wrist, fingers, neck and shoulders. The results revealed that by using conventional *jholi*/bag, the rural women could pick up to 25-30 kg of cotton in 7-8 hrs. and earn about Rs. 300- 350/- per day but by using cotton picking bag they could pick 35-40 kg. of cotton in 7-8 hour, thus earning about Rs. 400-550 per person per day. Output of cotton picking was found to be more with the help of cot bag. Majority found it to be highly acceptable (85.50%). Overwhelming majority (92.00%) perceived that using cot bag reduced pain in their shoulders (93.00%), backache (96.00%) and pain in hands (52.50%) and overall it helped in reducing the drudgery of women to a considerable extent. Adequate rest pauses coupled with training on use of proper body postures along with light exercises for back and shoulders are required to delay the onset of fatigue. Keeping in view the high acceptability of cot bag among rural women its promotion through Krishi Vigyan Kendras is suggested through vocational trainings imparting knowledge on drafting, cutting and stitching of cot bags.

Key words : Cot bag, Cotton picking, musculoskeletal problems

India is world's largest producer of cotton. Cotton production in India is estimated to have reached 36.1 million bales in the FY 2019 and cotton yarn accounts for the largest share in total yarn production. Women are involved in most of the agricultural operations in Haryana *viz.,*, transplanting, weeding, harvesting, post-harvest activities like- picking and plucking, while in other agricultural related activities, they share work with men folk. Hisar is a pre-dominantly cotton growing district. Jhajjar district has also got increased cotton growing area in past few years. In Haryana, the cotton area includes five major districts namely Sirsa, Fatehabad, Hisar, Jind and Bhiwani that constitute 90 per cent of crop in the state. Cotton picking is the tedious job exclusively handled by women folk. In Haryana, average 7-8 hours are spent daily in cotton picking between 50-60 days a year. These jobs involve considerable amount of drudgery. Drudgery is conceived as physical and mental strain, fatigue, monotony and hardship experienced by human beings. Traditionally, women in Hisar district uses a cloth sheet/ head cloth for collecting picked cotton by tying it in the form of bag on their shoulders and back, while women in Jhajjar district mostly uses gunny/ plastic bags. 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. On the other hand use of gunny bags/ plastic bags put unneccery pressure on their hands and drastically reduce their ability to pick cotton. To mitigate these problems, cotton picking bag developed by CCS HAU, Hisar was recommended and promoted among rural women of Hisar and Jhajjar district. 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

1. Assessment of socio-economic and work profile of women involved in picking cotton.
2. Studying musculo-skeletal discomforts perceived by women while performing activity.
3. Ascertaining acceptability of cot bag for selected parameters.

MATERIALS AND METHODS

The study was conducted in the month of October- November (2016-2019 at cotton farms of four villages *viz.,*, Kirtan, Ladwa, Talwandi Rana and Sadalpur of Hisar districts and four villages of Jhajjar district *viz.,* Ukhalchana kot, Sikanderpur, Bajitpur and Jondhi, thus compromising a data of 200 rural women engaged in cotton picking. 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. 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 DISCUSSION

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.

Perusal of data in Table 1 reveals that overwhelming majority of respondents falls in the age group of 20-40 years of age (76.00%) followed by those who were up to 20 years of age (15.50) and above 40 years of age (8.50). Majority was educated up to primary level (55.50%), however 20.00 % were illiterate. Remaining were educated up to high school level (24.00 %) while small percentage (0.50 %) have got formal education up to graduate level. Majority of respondents were having a low family education status (59.50%) followed by those who were having medium level (40.50 %), while just 0.50 % had high level of education. Most of the respondents were married (85.00 %), having a joint family system (62.00%) and a family size between 5-7 members (66.00 %).

Table 1. Socio-personal profile of respondents N=200

Socio-personal Variables	Hisar(f/%)n=100	Jhajjar(f/%)n=100	**Total**
Age			
Upto 20 years	13	18	**31 (15.50)**
20-40 years	80	72	**152 (76.00)**
Above 40 years	7	10	**17 (8.50)**
Education			
Illiterate	32	8	**40 (20.00)**
Upto primary	44	67	**111 (55.50)**
Upto high school	23	25	**48 (24.00)**
Graduate	1	-	**1 (0.50)**
Family Education Status			
Low	61	57	**118 (59.50)**
Medium	38	43	**81 (40.50)**
High	1	-	**1 (0.50)**
Marital Status			
Unmarried	19	11	**30 (15.00)**
Married	81	89	**170 (85.00)**
Family Type			
Nuclear	31	45	**76 (38.00)**
Joint	69	55	**124 (62.00)**
Family Size			
Up to 4 members	29	21	**50 (25.00)**
5-7 members	64	68	**132 (66.00)**
Above 7 members	7	11	**18 (9.00)**

Regarding Economic profile of the respondents, data in Table 2 indicates that agricultural labourer was the main occupation of half of the respondents (50.00%) followed by about one-third respondents (31.00%) who had agriculture occupation. Only few (1.00 %) were in govt. service. Monthly family income below Rs.10,000/- for 45.00 % of the respondents followed by 42.00 % who had income between Rs. 10,000-15,000 and 13.00 % were having monthly income above Rs.15,000.

Table 2. Economic profile of respondents N=200

Economic Variables	Hisar(f/%)n=100	Jhajjar(f/%)n=100	**Total**
Occupation			
Agriculture	41	21	**62(31.00)**
Private Sector	3	17	**20(10.00)**
Govt. Service	2	-	**21(1.00)**
Business/self employed	7	9	**16(8.00)**
Agricultural Labourer	47	53	**100(50.00)**
Monthly Income			
Below Rs.10,000/month	62	28	**90 (45.00)**
Rs.10,000-15,000/month	29	55	**84 (42.00)**
Above Rs.15,000/month	9	17	**26 (13.00)**

Perusal of data in Table 3 indicates that output of cotton picking registered improvement after using of cot bag by women. There was an apparent shift in the proportion of women picking cotton 40 Kg and above per day particularly in the Hisar district of Haryana. The increase in the amount of cotton picked was due to convenient collection of cotton in the improved cot bag. Unlike the traditional jholi, cot bag adjusts well on the shoulder and head of the workers without interfering in their hand and body movements. Hence, it can be concluded that cot bag showed better work output than existing traditional jholi.

Musculo-skeletal discomfort : Figure 1 shows the musculoskeletal discomfort perceived by cotton pickers. As hands are mainly involved continuously in cotton picking so very severe pain was reported in fingers and palms (m.s. = 4.85 and 4.7 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. = 4.35), wrists (m.s. = 4.4) and lower back (m.s.= 4.1). Severe to moderate discomfort was reported in shoulders (m.s. = 3.95), thighs (m.s.= 3.2) and upper back and feet (m.s. = 3.4 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 the reason that they use to stoop and change

Table 3. Increase in cotton picking/day by cotton picking bag N=200

Cotton picking/ day	By traditional Method			By cotton picking bag		
	Hisar (f/%) n=100	Jhajjar (f/%) n=100	**Total (%)**	Hisar (f/%) n=100	Jhajjar (f/%) n=100	**Total (%)**
Upto 20 Kg.	11	67	**78 (39.00)**	3	49	**52 (26.00)**
20-40 Kg.	85	33	**118 (59.00)**	43	51	**94 (47.00)**
40 Kg. and above	4	-	**4 (2.00)**	54	-	**54 (27.00)**

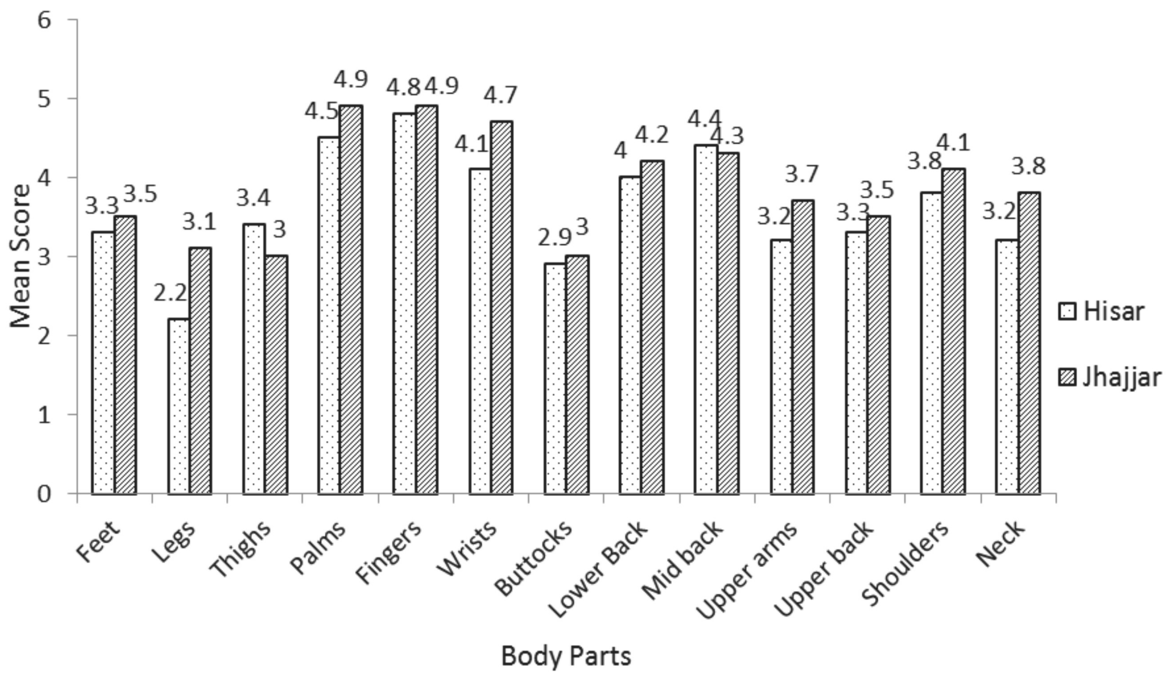

Fig. 1 Magnitude of Musculoskeletal Discomfort perceived by Women

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 pocket of bag at the 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 hung on their shoulders which they occasionally shifted to their head to impart temporary relief to shoulders.

Data in Table 4 reveals that majority of women were highly relieved (71%) and relieved (28%) by using cot bag. Majority (80%) indicated that there work output was highly improved. It was considered highly acceptable and acceptable (81% and 19%, respectively) by respondents. On field acceptability of cot bag, it was perceived to be highly acceptable by majority of women (85.50%). Data further indicate that overwhelming majority perceived reduction of pain in shoulder (93%), followed by neck and head (72.50%) and legs and thighs (56.50%). Regarding improvement in work efficiency, 99 per cent women reported picking more cotton by using cot bag in comparison to traditional jholi. Majority (98%) felt less fatigue on using cot bag, reduced back pain (96%) and less pain in hands (52.50%). Cot bag helped in reducing the drudgery of 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. 400-550/day in comparison to traditional method of cotton picking where they were plucking

Table 4. Acceptability parameters for Cot Bag N=200

Parameters	Hisar(f/%)n=100	Jhajjar(f/%)n=100	**Total**
Biomechanical Stress			
No relief	-	-	-
Moderate relief	2	-	**2 (1.00)**
Relieved	38	18	**56 (28.00)**
Highly relieved	60	82	**142 (71.00)**
Work Output			
No improvement	-	-	-
Moderate relief	5	-	**5 (2.50)**
Improved	24	11	**35 (17.50)**
Highly improved	71	89	**160 (80.00)**
Tool Factor			
Not acceptable	-	-	-
Needs modification	-	-	-
Acceptable	26	12	**38 (19.00)**
Highly acceptable	74	88	**162 (81.00)**
Field Acceptability			
Not acceptable	-	-	-
Needs persuasion	-	-	-
Acceptable	21	8	**29 (14.50)**
Highly acceptable	79	92	**171 (85.50)**
Health Related			
Reduce pain in shoulder	92	94	**186 (93.0)**
Reduce pain in neck & hand	68	57	**145 (72.50)**
Reduce pain in legs & thighs	50	63	**113 (56.50)**
Work Efficiency Related			
Increase work efficiency	70	82	**152 (76.00)**
Pick more cotton as compared to conventional bag	98	100	**198 (99.00)**
Drudgery Reduction Related			
Less fatigue as compared to conventional bag	96	100	**196 (98.00)**
Reducing backache	100	92	**192 (96.00)**
Less pain in hands	54	89	**105 (52.50)**

*Multiple responses

approximately 40 kg. cotton in 7 hours earning Rs. 300-350/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.

CONCLUSION

Summarizing, cotton picking is primarily women's responsibility in most part of India especially in Haryana. On an average women spend 7-8 hours in picking cotton collecting 25-30 kg of cotton per day during harvesting season, spending 50-60 days in an year. Cotton picking using traditional jholi results in various musculoskeletal problems for 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 (93.00%) perceived that using cot bag reduced pain in their shoulders, back (96.00%) and legs and thighs (56.50%) and overall helped in reducing the drudgery of a women to a considerable extent. This is predominantly due to the reason that cot bag is evenly distributed over shoulder to hip region helping 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, thereby earning Rs. 400-450 per day in comparison to traditional method of cotton picking where they were picking approximately 20-25 kg cotton in 7 hours and earning Rs. 300-350/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 the standard of living of families.

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PKV Hy 2 BG II : Successfully commercialized first *Bt* cotton hybrid of public sector in Maharashtra

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In current decade, India is maintaining leading position in cotton acreage in the world, China is leading in terms of cotton production and United States is ahead in export of cotton. On the productivity front Australia is leading with average yield of 1814 kg/ha, followed by China (1726 kg/ha) and Brazil (1636 kg/ha). India is way behind in productivity at 507 kg lint/ha. After successful launch of first commercial cotton hybrid H-4 in 1970 in India, Dr. PDKV, Akola released cotton hybrid PKV Hy 2 in 1981 for Maharashtra State. This hybrid is having high yield potential and suitable for rainfed condition and due to dense hairy leaves; it is tolerant to major sucking pests. This hybrid was not only popular amongst farmers of Maharashtra but also covered major cotton growing area of central zone soon after its release due to its wider adaptability. But after introduction of *Bt* cotton technology in 2002, farmers started growing *Bt* cotton hybrids and area under PKV Hy 2 was shrunken and replaced by *Bt* cotton hybrids. But farmers could not forgot the performance of PKV Hy 2 and they were continuously demanding *Bt* version of PKV Hy 2 to the Dr. PDKV and MSSCL. So, considering the demand of the farmers, Dr. PDKV, Akola and MSSCL, Akola has signed a MoU on 28 January 2014 to convert PKV Hy 2 in *Bt* version. Accordingly, a well defined BG II gene introgression programme in parents of PKV Hy 2 was initiated by both organizations.

Chronology of Transgenic *Bt* Cotton project:

- **28th January 2014:** MoU was signed between Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and Maharashtra State Seeds Corporation Limited, Akola for the conversion of PKV Hy-2 into BGII version.
- **17th May 2014:** Agreement was executed with Mahyco Monsanto Biotech India Private Limited (MMB), Mumbai for getting sublicense for BGII (MON 15985 event) technology.
- As per MoU, Dr. PDKV, Akola has supplied nucleus seeds of parental lines of cotton PKV Hy-2 to MSSCL.
- During the course of conversion of parental lines into BG II version using back cross breeding, the technical support as and when required was extended by the University scientists to

Table 1. Performance of PKV Hy 2 BG II in SAU trials for seed cotton yield (kg/ha) during 2016-2017

S.N.	Name of Entry/	Location (s)			Average	Percent increase over checks			
		Akola	Nanded	Jalgaon	(Kg/ha)	H-8 BGII	H-6 BGII	Bunny BGII	RCH-2 BGII
1	**PKV Hy-2 BGII**	**2479**	**2404**	**2112**	**2331.67**	**24.42**	**31.76**	**48.48**	**32.38**
2	H-8 BGII (C)	1994	1920	1708	1874.00				
3	H-6 BGII (C)	1792	1890	1627	1769.67				
4	Bunny BG II (C)	2017	1610	1084	1570.33				
5	RCH-2 BG II (C)	2053	1900	1331	1761.33				
	SE ± (m)	**174.2**	**163.3**	**136.10**					
	CD at 5%	**494.74**	**452.44**	**261.76**					
	CV	**13.10**	**14.38**	**12.45**					

Table 2. Data on Bollworm complex damage at harvest at Dr. PDKV, Akola during 2016-2017

Sr. No.	Entries	Open boll damage due to BWC (%)	Locule damage due to BWC (%)	Locule damage due to PBW (%)
1	**PKV Hy-2 BGII**	**17.93**	**7.23**	**5.68**
2	H-8 BGII (C)	16.06	5.16	3.87
3	H-6 BGII (C)	22.51	7.32	6.04
4	Mallika BG II (C)	22.71	7.92	6.38
5	Bunny BG II (C)	26.89	10.43	7.37
6	RCH-2 BG II (C)	24.50	8.78	6.67
7	PKV Hy-2 (C) (Non *Bt*)	39.04	16.67	13.70

Table 3. Data on Bollworm complex damage at harvest at VNMKV, Nanded during 2016-2017

Sr. No.	Name of Entry	% Open boll damage	
		Boll basis OV	Locule basis OV
1	**PKV Hy-2 BGII**	**8.47**	**6.40**
2	H-8 BGII(C)	9.43	6.27
3	H-6 BGII(C)	12.67	5.90
4	Bunny BG II (C)	14.43	6.37
5	RCH-2 BG II (C)	13.07	5.90

MSSCL time to time for the successful development of *Bt*. Cotton hybrids.

- **June 2014:** Trait introgression and subsequent backcrossing progrramme was started as per protocol given below.
- **June 2016 :** The F_1 seeds of PKV Hy-2 BGII were produced and SAU trials were conducted at Akola, Jalgaon and Nanded locations for judging the yield

Table 4. Data on sucking pest infestation at ARS, Jalgaon during 2016-17

Sr. No.	Name of Entry	No./3 leaves Aphids	No./3 leaves Jassids	No./3 leaves Thrips	No./3 leaves White Fly
1	**PKV Hy-2 BGII**	**1.80**	**2.87**	**2.53**	**2.73**
2	H-8 BGII (C)	2.87	4.67	3.33	3.73
3	H-6 BGII (C)	2.93	5.20	3.13	3.27
4	Bunny BGII (C)	2.73	5.07	3.27	2.93
5	RCH-2 BGII (C)	2.93	4.60	3.33	3.53

performance, insect pest reaction and fibre qualities. The data of SAU trials is presented in Table 1 to Table 8.

- **September 2016:** As per the regulatory

June, 2014	Non *Bt* Parental Lines of PKV Hy 2		Donar of BG II
	AK-32 (F)	X	BG II Donar
	DHY-286-1 (M)	X	
		↓	
		F_1	
November, 2014	F_1	X	Recurrent Parent (RP) (AK-32 & DHY-286-1)
		↓	
		$BC_1 F_1$	
May, 2015	$BC_1 F_1$	X	Recurrent Parent (RP)
		↓	
		BC_2F_1	
October, 2015	BC_2F_1	X	Recurrent Parent (RP)
	Selfing ↓	↓	
March, 2016	BC_2F_2	BC_3F_1	X Recurrent Parent (RP)
			↓
	Zygocity evaluation & Identification of Homozygous BG II plants with recovery of RP & crossing of AK-32 BG II plants with DHY-286-1 BG II plants		BC_4F_1 ↓
June, 2016	SAU Trials at Akola, Nanded and Jalgaon ↓		
September, 2016	Strip Trial of PKV Hy-2 BG II at MSSCL, Akola to get NOC, LOC, Bioefficacy & protein profiling data from technology provider(MMB) ↓	BC_4F_1	X Recurrent Parent (RP) ↓

April, 2017	Submission of Release proposal of PKV Hy-2 BGII to DAC-ICAR, New Delhi		
November, 2017	Approval for commercial release in Maharashtra under rainfed condition	BC_5F_1	
February, 2018	Received CAMS sales permission		
May, 2018		BC_5F_2	Zygocity evaluation & Identification of Homozygous BG II plants with recovery of RP
June, 2018	Demonstrations on Universities Research Stations. Seed production of PKV Hy-2 BG II		
June, 2019	Selling of 15000 packates in Maharashtra		

Signing of MoU between Dr. PDKV, Akola & MSSC Ltd, Akola

Supply of Donor seeds from MMB

0

Visit of Hon'ble Vice chancellor, Dr. PDKV, Akola & Hon'ble Managing Director , MSSCL, Akola to PKV Hy-2 BGII demonstration

Table 5. Data of Sucking pest grade at harvest at Dr. PDKV, Akola during 2016-2017

Sr. No.	*Bt* Hybrid	Sucking Grade
1	**PKV Hy-2 BGII**	**I**
2	H-8 BGII (C)	II
3	H-6 BGII (C)	II
4	Mallika BGII (C)	III
5	Bunny BGII (C)	III
6	RCH-2 BGII (C)	III
7	PKV HY-2 N*Bt* (C)	I

requirements, to generate protein profiling and Bioefficacy data, a strip trial was conducted at Research & Development farm of MSSC Ltd, Akola.

- **April 2017:** Proposal of PKV Hy-2 BGII was submitted to standing committee of DAC-ICAR, New Delhi for getting approval for its commercial release in Maharashtra State under rainfed

Table 6. Data of sucking pest infestation at VNMKV, Nanded during 2016-17

S N	Name of Entry	Aphids		Jassids		Thrips		Whitefly	
		OV	TV	OV	TV	OV	TV	OV	TV
1	**PKV Hy-2 BGII**	**9.00**	**3.06**	**8.33**	**2.97**	**38.00**	**6.20**	**22.7**	**4.83**
2	H-8 (C)	6.33	2.61	14.87	3.91	26.13	5.15	11.47	3.45
3	H-6 (C)	5.87	2.52	11.87	3.51	20.67	5.59	12.40	3.59
4	Bunny BG II (C)	12.93	3.66	20.60	4.59	27.93	5.33	14.20	3.83
5	RCH-2 BG II (C)	6.13	2.57	18.27	4.33	30.53	5.56	25.40	5.08
	F test		**Sig**		**Sig**		**Sig**		**Sig**
	SE		**0.09**		**0.07**		**0.1**		**0.07**
	CD at 5%		**0.25**		**0.2**		**0.29**		**0.21**
	CV %		**5.4**		**3.26**		**3.31**		**3.11**

Table. 7. Fibre quality data in SAU trial at Dr. PDKV, Akola during 2016-2017

Sr. No.	Name of test hybrid/checks	UHML (mm)	UI %	MIC ug/in	Tenacity 3.2 mm (g/tex)	EL %
1	**PKV Hy-2 BGII**	**26.9**	**83**	**4.4**	**26.6**	**5.3**
2	H-8 BGII (C)	28.3	83	3.9	28.4	5.3
3	H-6 BGII (C)	28.2	83	3.9	28.1	5.4
4	Mallika BGII (C)	30.2	84	4.2	30.2	5.1
5	Bunny BGII (C)	31.6	84	3.9	29.0	5.3
6	RCH-2 BGII (C)	29.3	84	4.0	28.3	5.4
7	PKV Hy-2 (C) (N*Bt*)	26.6	82	4.5	25.8	5.1

Table 8. Fibre quality data in SAU trial at VNMKV, Nanded during 2016-2017

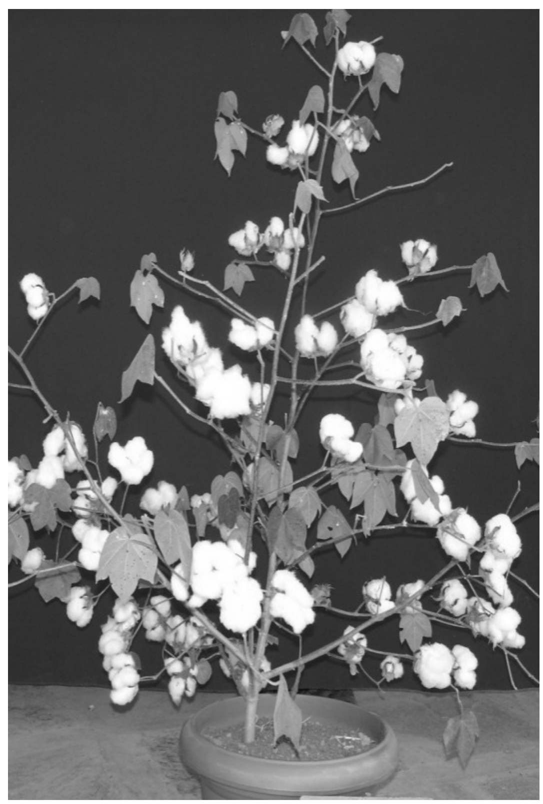
Sr. No.	Name of test hybrid/checks	UHML (mm)	UI	MIC	Tenacity g/tex
1	**PKV Hy-2 BGII**	**27.6**	**82**	**3.8**	**30.8**
2	H-8 BGII (C)	27.7	82	3.0	29.6
3	H-6 BGII (C)	28.1	82	3.3	30.7
4	Bunny BGII (C)	30.4	82	3.3	29.8
5	RCH-2 BGII (C)	28.4	82	3.6	29.1

Important features of PKV Hy-2 BG II

Parent	:	AK-32 BG II x DHY-286-1 BG II'
Year of Release	:	2017
Breeding method	:	Heterosis Breeding
Recommended ecology	:	Kharif, recommended for Maharashtra state under rainfed condition
Varietal Characters	:	Leaves densely hairy with 3-5 shallow cutted broad lobes, yellow flower with petal spot and cream anthers
Duration	:	170-180 days
Reaction to major pests/diseases	:	Resistant to Jassids and tolerant to Bacterial blight
Staple length	:	26.5-27.5 mm
Fibre strength	:	26-27 g/tex
Spinability count	:	40's
Seed index	:	8-9 g
Boll weight	:	3.5-4.0 g
Ginning percentage	:	35-36 %
Average Yield	:	20-22 q/ha

condition.

- **November 2017:** PKV Hy-2 BGII was approved by DAC-ICAR for its commercial release in entire Maharashtra State under rainfed cultivation.
- **February 2018:** Received sales permission from Commissioner of Agriculture (MS)
- Few large scale demonstrations were organized on research stations of Agricultural Universities viz, Dr. PDKV, Akola, VNMKV, Parbhani & MPKV, Rahuri.
- Large scale seed production of PKV Hy 2 BG II was undertaken in Gujrat State
- About 15000 seed packets were sold during Kharif, 2019.
- Farmers are showing great deal of satisfaction towards the performance of PKV Hy 2 BGII.



PKV Hy-2 BG II

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Utilizing secondary gene pool for enhancing trait value in cotton

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Cotton belongs to genus *Gossypium* of Malvaceae family. Genus *Gossypium* includes about 50 species which are distributed in arid to semi-arid regions of the tropics and subtropics (Wendel and Cronn, 2003). Recently, two more tetraploid *Gossypium* species namely *G. ekmanianum* (Grover *et al.*, 2015) and *G. stephensii* (Gallagher *et al.,* 2017) have been recognized. Forty-five cotton species are diploid (2n=2x=26) and seven are allotetraploid (2n=4x=52). *G. arboreum* and *G. herbaceum* are the two diploid cultivated cotton species popularly known as Old World, Asiatic or *desi* cottons. Among the tetraploid cottons, *G. hirsutum* and *G. barbadense* are cultivated. *G. hirsutum* contributes about 95% of the total world cotton production (Trapero *et al.,* 2016). India is the only country to grow all the four species of cultivated cotton and the interspecific hybrids. Though cotton is cultivated in more than 60 countries, yet nearly 90 per cent of cotton is produced by 10 countries *viz.*, India, China, USA, Pakistan, Brazil, Uzbekistan, Australia, Burkina Faso, Turkey, and Turkmenistan.

Single-letter genome symbols have been designated to related clusters of *Gossypium* species based on observations of pairing behavior, chromosome sizes, and relative fertility in the interspecific hybrids. Presently, eight diploid genome groups (A, B, C, D, E, F, G and K) are recognized (Endrizzi,Turcotte and Kohel 1985, Stewart, 1995). *Gossypium* species can be further grouped into three gene pools based on ability to generate fertile hybrids between donor and recipient species and frequency of homeologous recombination (Harlan and de Wet 1971). By following these criteria, Stewart (1995) assigned the *Gossypium* species into primary, secondary and tertiary gene pools. The wild, commensal and feral forms of *G. hirsutum* and *G. barbadense*, including other tetraploid species constitute the primary gene pool.

The secondary gene pool comprises species belonging to A, B, D and F genomes. *G. herbaceum* and *G. arboreum* are the A-genome species with genome designations A_1 and A_2, respectively. The former species is still found in the wild state in Africa, whereas, only cultivated forms are known for the latter species. *G. anomalum*, *G. triphyllum*, *G. captis-viridis*, (*G. trifurcatum*) found in Africa and Cape Verde Islands harbour B-genome. *G. thurberi*, *G. armourianum*, *G. harknessii*, *G. davidsonii*, *G. klotzschianum*, *G. aridum*, *G. raimondii*, *G. gossypioides*, *G. lobatum*, *G. trilobum*, *G. laxum*, *G. turneri*, and *G. schwendimanii* (each carrying a D-genome) primarily occur in Mexico, with range extensions into Peru, Galapagos islands, and Southern Arizona (Wang *et al.*, 2018). There is only one F-genome species, *G. longicalyx* which is endemic to East Africa. Secondary gene pool species are diploid, so initial interspecific hybrid with tetraploid cotton is a usually a sterile triploid.

Tertiary gene pool comprises of C, E, G, and K genomes. These species are difficult to hybridize with tetraploid cotton and level of genetic recombination is low. A recent review by Wang *et al.* (2018) on the designations of *Gossypium* genomes and chromosomes is worth reading. The tetraploid *Gossypium* species originated about 1 - 2 million years ago from the hybridization between two diploid species, one each from the old world [resembling extant *G. herbaceum*, A_1) and the new world (resembling extant *G. raimondii*, D_5) followed by chromosome doubling. Tetraploid cottons had a monophylectic origin (Grover *et al.*, 2012). Substantial variation among the genome sizes of the diploid cotton species (885 MB in D-genome species through 2570 MB in K-genome species) has been observed (Hendrix and Stewart, 2005).

Cultivated diploid cottons were the predominantly cultivated cotton species in India. In 1950, *G. arboreum* and *G. herbaceum* together occupied about 97 per cent cotton area in the country. However, due to several reasons including the commercialization of bollworm resistant transgenic Bt *G. hirsutum* hybrids, area under *desi* cottons has largely been displaced. Several reports suggesting narrow genetic base of dominating cotton species *G. hirsutum* are available. Cultivated diploid cottons are important reservoir of genes of economic importance. For example, Asiatic cottons have contributed high fibre strength and resistance to *Pectinophera gossypiella*, *Puccinia cacabata*, *Xanthomonas campestris* pv. *malvacerum* (Fryxell, 1984; Meredith, 1991). *G. arboreum* is also known to be resistant to cotton leaf curl disease (Singh *et al.*, 1997, Rashida *et al.*, 2005; Gupta *et al.*, 2006), a serious threat to American cotton cultivation in North zone cotton growing states of India and Pakistan. Asiatic cottons are sources of resistance to the sucking pest complex (hoppers, thrips, mites and whiteflies) (Mehetre *et al* 2004).Thus, it has been suggested that assessment of genetic diversity of *G. arboreum* is important for all the cotton breeding programmes including those of American cotton (Stanton *et al.*, 1994).

Some of the successful examples of introgression in cotton include: Beasley (1942) transferred gene for superior lint strength in *G. hirsutum* through amphidiploid of *G. thurberi* x *G. arboreum*. Resistance to rust caused by *Puccinia cacabeta* in *G. anomalum* and *G. arboreum* was reported by Blanks (Blank) and Leathers (1963). Bacterial blight resistance genes from *G. arboreum* were transferred into tetraploid cotton (Knight 1948, 1953). Wheeler *et al* (1999) reported that *G. arboreum* was resistant to fungus *Thielaviopsis basicola* causing black root rot. *G. arboreum* lines immune to grey mildew caused by *Ramularia areoala* are available (Mohan *et al* 2000, Mukewar and Mayee 2001).

A new synthetic allotetraploid between *G. herbaceum* and *G. australe* was produced by Liu *et al* (2015) with the objective to transfer “Glandless-seed and Glanded plant” trait to the upland cotton. The putative interspecific F_1 hybrid plant appeared to be highly male and female sterile 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, one S_1 plant was rescued which set five bolls to give 22 seeds. 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.

The reniform nematode (*Rotylenchulus reniformis*) has become an important plant-parasitic nematode of American cotton in the southern US. *G. longicalyx* has been reported to be immune to reniform nematode (Yik and Birchfield, 1984). “Triple species hybrid” technique (Bell and Robinson, 2004; Konan *et al.*, 2007) was used to overcome the genetic incompatibility. *G. hirsutum* x *G. longicalyx* x *G. armourianum* (HAL), *G. hirsutum* x *G. herbaceum* x *G. longicalyx* (HHL) and *G. hirsutum* x *G. thurberi* x *G. longicalyx* (HTL) were developed using this strategy. Genes conferring resistance to nematodes have been introgressed and mapped from *G. longicalyx* (Dighe *et al.*, 2009) and *G. aridum* (Romano *et al.*, 2009).

Cotton leaf curl disease (CLCuD) has become a constant threat to successful American cotton cultivation in the North Indian cotton growing states. Substantial yield losses and adverse effects on fibre quality due to CLCuD have been reported in the susceptible American cotton varieties. The losses to Pakistan economy are calculated to have been US $ 5 billion in the five years between 1992 and 1997 (Briddon and Markham 2000). CLCuD is caused by a whitefly *Bemisia tabaci* (Genn.) transmitted Gemini virus complex. Most of the established resistant/ tolerant cultivars/germplasm of American cotton have become susceptible to this disease. Therefore, identification and use of new sources of CLCuD resistance has become a very important research activity. In this context, *G. armourianum* (DD), a related non-progenitor wild cotton species and a synthetic amphiploid (derived from non-progenitor A- and D-genome cotton species) were evaluated for their reaction to CLCuD at Punjab Agricultural University (Pathak *et al* 2016). Both of these stocks were observed to be free from disease under natural conditions. For artificial screening, whiteflies were initially allowed to suck the sap of CLCuD infected American cotton plants for 24 hours. Then, the viruliferous whiteflies were collected from the diseased plants and were allowed to feed on the plants of synthetic tetraploid and *G. armourianum* Acc. PAU 1. No symptoms of CLCuD on these stocks were observed throughout the crop season, whereas susceptible variety F 846 manifested severe symptoms of the disease such as vein thickening, curling of the leaves, leaf enation etc. Total genomic DNA from the diseased American cotton plants (positive control), synthetic tetraploid and *G. armourianum* was isolated. Virus specific primer was used to amplify the viral DNA from the samples. Virus specific bands were observed in the positive control and the synthetic, but not in *G. armourianum*. Results indicate that the synthetic tetraploid is a symptomless carrier/tolerant, whereas, *G. armourianum* is resistant to CLCuD. An interspecific hybrid between *G. hirsutum* (female) and *G. armourianum* (as pollen parent) was developed without any difficulty (Kaur *et al*, 2016). However, BC_1F_1 plants was obtained with great difficulty. BC_2F_1 population showed segregation for CLCuD resistance and susceptibility. Similarly, crosses between synthetic amphidiploid (as the female parent) and natural allotetraploid *G. hirsutum* as the pollen parent were attempted. A total of 3158 flowers were pollinated and 28 mature crossed bolls containing 25 F_1 seeds were obtained. The F_1 hybrids were observed to be free from disease. BC_2F_1 (it should be BC_1F_1 and BC_1F_2 here) population segregated for CLCuD resistance and susceptibility. Mapping of the gene(s) conditioning resistance to CLCuD in both the populations is under progress.

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CROP PRODUCTION, MECHANIZATION AND ECONOMIC DEVELOPMENT

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Seed cotton yield and sucking pest dynamics in American cotton (*Gossypium hirsutum* L.) as affected by genotypes, crop geometry and nutrient levels under semi arid conditions

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ABSTRACT : A field investigation was undertaken to evaluate performance of two American cotton cultivars under different plant geometry and nutrition levels. The experiment arranged in split plot design with 3 replications has been conducted during *kharif* 2017 at PAU Regional Station, Faridkot. The treatments comprised of two cotton cultivars in main, three plant geometries in sub and three nutrition levels in sub-sub plots. Experimental findings revealed that F2228 resulted in significantly higher seed cotton yield by 919 kg/ha over that of H1098i. Among tested crop geometries, seed cotton yield was found to be 2323, 2242 and 1920 kg/ha for 67.5x 60, 67.5x45 and 67.5 x30cm, respectively. Nutrition levels failed to exert any significant effect on seed cotton yield. However, among sucking pests, whitefly population was significantly affected at 100 days after sowing (DAS) and that too for planting geometry and nutrient levels. These results indicated 75:30:50:25 kg of N,P,K and Zn /ha to be appropriate among tested nutrient levels which favored low pest status. Study also revealed that higher N application rates resulted into significant increase in whitefly population at 100 DAS. A similar trend was also observed for jassid population which was least at lowest rate of N application. A planting geometry of 67.5 x 60 cm, nutrient level of 75:30:50:25 kg of N,P,K and Zn /ha and F2228 has been found to be the better option for higher seed cotton yield under semi arid irrigated conditions of North India.

Cotton also known as **"White Gold"** is a valuable fiber crop being grown throughout the globe. During 2017-18, India remained the leading country in terms of area (122.35 lakh ha) under cotton cultivation and raw cotton production (377.00 lakh bales of 170 kg each) in the world but still the productivity (524 kg/ha) is too low. However, in terms of productivity, Australia (2202 kg/ha) ranks first followed by China (1761 kg/ha) and other countries (Anonymous, 2018).Cotton is primarily grown for fiber use in distinct agro-climatic zones of the nation, thus regarded as the main agricultural commodity of textile industry, supporting Indian economy. To address the rising fiber needs of the textile sector and global trade demands, cotton production needs to be boosted not only through the inclusion of more area under cotton cultivation but also through a focused emphasis on production practices such as plant geometry and nutrient management of potential genotypes for improving economic status of cotton growers. To minimize the competition among growing plants for plant nutrients and moisture, it is important to find out the right combination of plant geometry and nutrient dose to attain maximum cotton yield. Fulfillment of nutritional requirements of the cotton plant is essential for increasing yield and better quality. Nitrogen is primary nutrient essential for cotton plants which necessitate its supply at proper time and quantities. Productivity of cotton can be significantly enhanced by proper planting geometry and fertilizer doses (Kumar *et al.,* 2011). Growing cotton with closer plant density lead to higher lint yield, maximum net returns and benefit cost ratio as compared to low plant density due to more picked bolls/unit area (Kumar *et al.,* 2017). Therefore, knowledge of adequate plant geometry and nutrition level is essential not only to save the input investment during cultivation, but also to augment the production through efficient utilization of resources. Therefore, present research work was undertaken with the objective to find out ideal crop geometry and optimum nutrition level to achieve better growth and productivity of two cotton cultivars.

MATERIALS AND METHODS

The field experiment has been conducted at PAU Regional Research Station, Punjab Agricultural University during *kharif* 2017. The soil texture of experimental site was loamy sand having pH 8.6, organic carbon 0.54 per cent, electrical conductivity of 0.23 m mhos, high in available phosphorus (29.8 kg/ha) and very high in available potash (578 kg/ ha). The experiment was conducted in split plot design having two genotypes in main plots (F2228 and H1098i) , three crop geometries (67.5 × 60, 67.5 × 45 cm and 67.5 × 30 cm) in sub plots and three nutrient levels ((i.e. F1: 75:30:50:25 kg, F2: 90:30:30:0 kg and F3 : 80:40:20:24 kg of N,P,K & Zn /ha, respectively) in sub-sub plots with 3 replications in a 36.45 m^2 plot size. Sowing was done at 5 cm depth by hand dibbling on April 28th, 2017. According to the treatments, half of nitrogen dose was applied at squaring stage and remaining half at flowering stage through urea. Basal application of full dose of phosphorus was applied through DAP, potash through MOP and zinc through zinc sulphate (21 per cent), just at the time of field preparation. Rest all management practices were carried as per university guidelines. The plant height (cm) was recorded from ground level to last unfolded leaf base at the top. The data on various growth and yield parameters were taken from ten randomly selected plants in each plot. Seed cotton yield was recorded on/plot basis from two manual picking and expressed as yield in kilograms kg/ ha. The experimental data were analyzed as per the standard procedure.

RESULTS AND DISCUSSION

Growth and yield parameters: The data on various growth and yield parameters has been presented in Table 1. The variety F2228 maintained superiority for plant height, boll count and seed cotton yield over that of H1098i. However, monopods and sympods were not significantly affected. Owing to better yield attributes like bolls/plant and higher boll weight, F2228 (2621 kg/ha) out yielded of H1098i (1702 kg/ha) by 919 kg/ha. Among planting geometry treatments, 67.5 cm × 30 cm (166.5 cm) produced significantly taller plants as compared to 67.5 cm × 45 cm (154.8 cm), and 67.5 cm × 60 cm

Table 1. Growth, yield and yield contributing characters of cotton under different treatments

Treatment	Plant height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield (Kg/ha)
Varieties						
F2228	166.0	1.18	24.0	46.9	3.13	2621
H1098-i	143.1	1.11	23.7	36.5	2.47	1702
CD (p=0.05)	12.6	NS	NS	7.1	0.25	410
Planting geometry (cm)						
67.5 x 60	142.4	1.14	26.1	47.7	2.94	2323
67.5 x 45	154.8	1.21	23.8	42.4	2.75	2242
67.5 x 30	166.5	1.07	21.8	35.1	2.71	1920
CD (p=0.05)	6.4	NS	NS	3.9	0.13	195
Nutrient levels (N:P:K:Zn/ha)						
75:30:50:25	153.9	1.05	24.1	41.1	2.78	2194
90:30:30:25	153.0	1.18	23.4	41.7	2.84	2094
80:40:20:24	156.8	1.19	24.1	42.4	2.79	2197
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Sucking pest population under different treatments

Treatments	80 days after sowing		100 days after sowing		
	Whitefly/3 leaves	Jassid /3 leaves	Thrip /3 leaves	Whitefly/3 leaves	Jassid/3 leaves
Varieties					
F2228	11.4	2.0	14.1	6.3	0.7
H1098-i	13.9	2.9	14.9	10.6	0.7
CD (p=0.05)	NS	NS	NS	NS	NS
Planting geometry (cm)					
67.5 x 60	12.6	2.9	16.6	8.3	0.8
67.5 x 45	12.2	2.4	12.4	9.0	0.8
67.5 x 30	13.3	2.2	14.6	8.0	0.7
CD (p=0.05 per cent)	NS	NS	NS	0.5	NS
Nutrient levels (N:P:K:Zn/ha)					
75:30:50:25	11.8	2.2	15.1	7.7	0.6
90:30:30:25	12.6	2.3	14.8	9.1	0.7
80:40:20:24	13.5	2.9	13.6	8.5	0.9
CD (p=0.05 per cent)	NS	NS	NS	1.0	0.21

(142.4 cm). Taller plants with narrow spacing were recorded because of more vertical growth due to competition among plants/unit area in line with findings of Singh *et al.,* (2012) and Rawal *et al.,* (2015). However, trend for other parameters like bolls/plant, boll weight was altogether reverse where better performance was evident at each wider geometry. Consequently seed cotton yield was highest under 67.5 × 60 cm (2323 kg) followed by 67.5 × 45 cm (2242kg), and lowest for 67.5 × 30 cm (1920kg). Seed cotton yield decreased with closer planting geometries due to both inter-plant and intra-plant competition as reported by Shukla *et al.,* (2014). Nutrition levels failed to exert any significant effect on seed cotton yield. Therefore the lowest level of N nutrition *i.e.* 75:30:50:25 kg of N,P,K and Zn /ha, was found to be the optimum.

Pest population studies: The data in Table 2 revealed that all the three types of treatments remained *at par* for pest status until 80 DAS. However, at 100 DAS, whitefly and jassid population varied significantly under certain treatments but thrip population remained *at par*. Whitefly population was significantly affected by planting geometry as well as nutrition levels. Among plant geometries, whitefly count remained 8.3, 9.0 and 8.0 / 3 leaves for 67.5 × 60 cm, 67.5 × 45 cm, 67.5 × 30 cm, respectively. Similarly, value was 7.7, 9.1 and 8.5 for 75:30:50:25 kg, 90:30:30:0 kg and 80:40:20:24 kg of N,P,K & Zn/ha, respectively. This clearly indicated that higher N application rates favored significant increase in whitefly population at 100 DAS. Jassid population also followed similar trend as a result of which it remained least at lowest rate of N application.

Present investigation concluded that cotton cultivar F2228 should be preferred and grown at a planting geometry of 67.5 × 60 cm and fertilized with 75:30:50:25 kg of N,P,K and Zn /ha so as to ensure minimum sucking pest infestation and less expenditure on pesticides and consequently better seed cotton yield coupled with higher returns.

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Adoption of drip fertigation for cotton is helping in doubling farmers income !

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ABSTRACT : Cotton is very important cash crop grown in India. It is also known as **"White Gold"**. It is cultivated in 122.6 lakh ha area and its productivity is very low 527 kg Lint / ha. In Maharashtra Cotton is cultivated on 42.27 Lakh ha and productivity is just 356 kg lint / ha. Though area under Cotton in Maharashtra is highest however productivity is lowest. Constraints of low productivity in Maharashtra are is mainly lack of irrigation facilities, erratic monsoon, no moisture available in a soil at boll development stages in Cotton grown areas. Most of the cotton crop cultivated as rainfed crop.

Maharashtra is a pioneer in adoption of drip irrigation technology in a country. Farmers has stared adoption of this technology from 1987/88.. Around 24 lakh ha area is brought under this micro irrigation technology in Maharashtra. Cotton farmers has started adoption of drip irrigation from year 2006. Around 4.28 lakh ha cotton area is brought under drip irrigation in Maharashtra. Results of pre monsoon cotton sowing under drip irrigation are amazing, Farmers has harvested Cotton yields from 1050 to 2161 kg lint / ha which is more than World's Cotton yield. Rain fall do not match with the growth stages of Cotton crop. Due to withdrawal of monsoon during boll development stages results low yields of cotton, drip irrigation maintains field capacity in soil, Water and nutrients are efficiently managed through drip fertigation technology which leads to get bumper yield of Cotton.

This model is now replicated in Gujarath , Madhya Pradesh, Andhra Pradesh. Yields of cotton is increased by 200 – 300 per cent by adoption of this technology. Farmers are yields are increased due to pre monsoon sowing, Hybrid *Bt* varieties, drip irrigation and fertigation technologies. Soil – water – plant relationships get maintained under drip irrigation, crop never get water stress at any stages, It also improves efficiency of fertilizers, minimizes dropping of squares, flowers. Also observed better boll development. Hence adoption of drip fertigation is a need of hour to improve Cotton productivity to get double farm income to cotton farmers.

Farmer Shri Narayan Ramchandra Thakur from Shahadadist Nandurbar has harvested bumper yield of seed cotton 123.32 q/ ha with reflush crop in 2016-2017 and in current year he has harvested 56.00 q/ha under Jain drip irrigation and fertigation (without reflush crop and due to cotton pink boll worm)

Hence adoption of drip fertigation is a need of hour to get bumper yield of cotton and get doubling farmers income.

Cotton is very important cash crop grown in India. It is also known as **"White Gold"**. It is cultivated in 117.6 lakh ha area and its productivity is very low 527 kg Lint / ha. Area under cotton has increased due to *Bt* technology. Farmers has started adoption of *Bt* varieties from year 2002. Almost more than 90 per cent *Bt* cotton is cultivated. In Central zone of cotton in Maharashtra Cotton is cultivated on 38.27 Lakh ha and productivity is just 356 kg lint / ha.Though area under cotton in Maharashtra is highest however productivity is lowest in a country. Constraints of low productivity in Maharashtra are is mainly lack of irrigation facilities, irregular monsoon, no moisture available in a soil at boll development stages in Cotton grown areas. Most of the cotton crop cultivated as rainfed crop. In MS 95 per cent Cotton is cultivated under rainfed conditions and only 5 per cent Cotton area is cultivated under irrigation.

- Jain Irrigation is a pioneer in promotion of drip irrigation technology. Farmers has started adoption of this technology from 1987-1988.

State wise area and yield of cotton year (2015-2016)

State	Area (Million ha)	Yield lint (Kg/ha)
Punjab	0.45	415.56
Haryana	0.59	550.91
Rajasthan	0.41	669.95
NORTHERN ZONE	**1.44**	**542.19**
Gujarat	2.76	646.5
Maharashtra	3.82	355.65
Madhya Pradesh	0.55	559.41
CENTRAL ZONE	**7.13**	**483.88**
Telangana	1.69	593.84
Andhra Pradesh	0.66	590.63
Karnataka	0.59	695.06
Tamil Nadu	0.11	809.52
SOUTHERN ZONE	**3.04**	**620.11**
Orissa	0.13	408
Others	0.02	1619.05
TOTAL	**11.76**	**527.49**

Around 20 lakh ha area is brought under this technology in Maharashtra. Jain irrigation has promoted concept of premonsoon cotton under drip irrigation at grass root level, organized campaigns aggressively. Orgainsed demonstrations of cotton under drip irrigation in 1995-1996 and organized farmers visits to drip rrigated Cotton fields. Also organized farmers melawas in drip irrigated cotton fields. Results of cotton under drip seed cotton yields were -

- 1. Shri RavindraRamdasPatil – Jarandi - 19 q/ac
- 2. Shri LaxmanNamdevPatil – Anturli - 21 q/ac
- 3. Shri PralhadDevramSapkale – Karanj - 17 q/ac

Cotton farmers has started adoption of drip irrigation from year 2005. Around 3.78 lakh ha Cotton area is brought under drip irrigation in Maharashtra. Results of premonsoon Cotton sowing under drip irrigation are amazing, Farmers has harvested cotton yields from 1050 to 2593 kg lint / ha which is more than World's cotton yield. Word's average cotton productivity is 746 kg lint / ha. Rain fall do not match with the growth stages n duration of Cotton crop. Due to withdrawal of monsoon during boll development stages and long dry spell in reproductive phases results low yields of cotton, drip irrigation maintains field capacity in soil, water and nutrients are efficiently managed through drip fertigation technology which leads to improve yield potential and get bumper yield of cotton. This model is now replicated in Gujarath , Madhya Pradesh, Andhra Pradesh. Yields of cotton is increased by 200 – 300 per cent by adoption of this technology. Yields are increased due to Premonsoon sowing, Hybrid *Bt* varieties, Drip irrigation and Fertigation technologies.

Seed cotton Yields -

• Under rainfed conditions	8 - 10 q/ ha
• Under flood irrigation	20 - 25 q/ ha
• Under drip irrigation	40 - 50 q/ ha

What is micro/drip irrigation? :

Micro/drip irrigation is described as regulated and show application of irrigation water through emitters or orifices at frequent intervals near the root zone of plant, over a longer period of time.

Soil – water – plant relationships get maintained under drip irrigation, crop never get water stress at any stages, It also improves efficiency of fertilizers, minimises dropping of squares, flowers. Also observed better boll development. Hence adoption of drip fertigation is a need of hour to improve cotton productivity to get double farm income to cotton farmers.

Principles of drip irrigation -

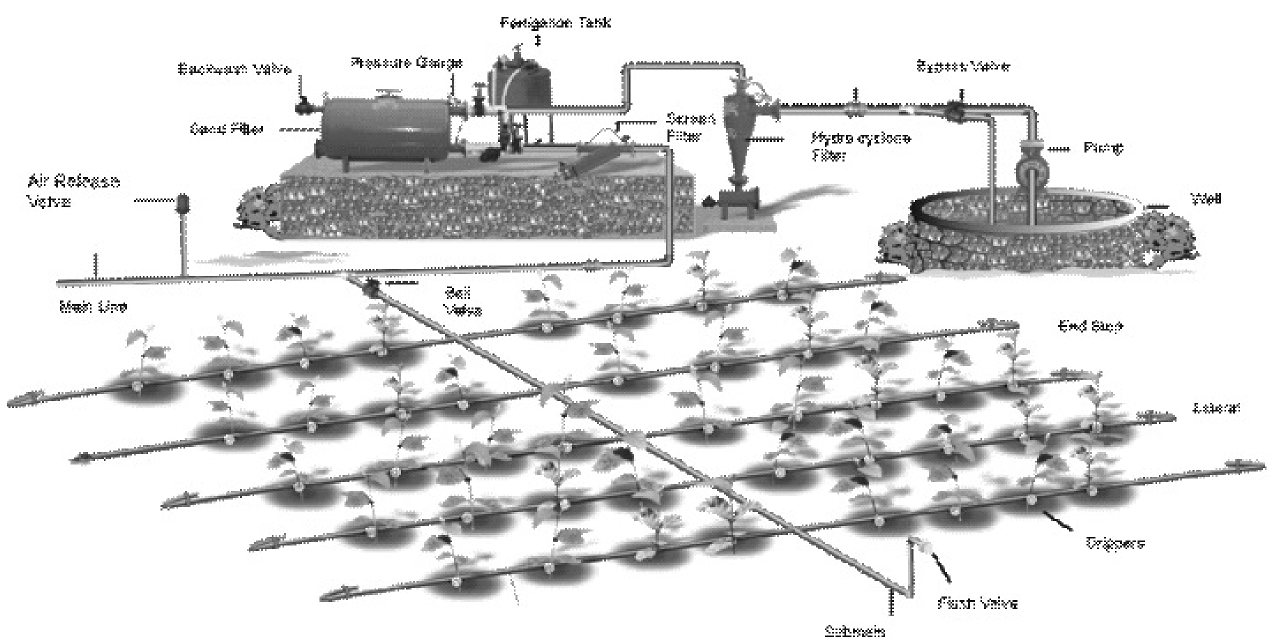
1. Water is applied at a low rate
2. Water is applied over a long period of time.
3. Water is applied at frequent intervals.
4. Water is applied via a low pressure delivery system.

Drip Irrigation in Cotton at a glance in India

- Maharashtra – 4.20 Lakh ha
- Gujarath - 3.89 Lakh ha
- MP - 0.40 Lakh ha
- AP / TL - 0.50 Lakh ha
- Karnataka - 0.30 Lakh ha

Constraints for low yield of cotton

- Untimely sowing.
- Lack of Irrigation facilities.
- Cotton cultivation in light and marginal soils.
- Imbalanced nutrition
- Poor agronomical practices.
- Heavy pest and diseases.



Results of drip irrigation in cotton

Research station	Water saving (%)	Yield increase (%)	Water requirement mm ha cm flood irrigation.	Water requirement mm ha cm drip irrigation	Crop flood yield kg/ha	Crop yield kg/ha drip
MPKV Rahuri	**43**	**40**	**895**	**511**	**2250**	**3140**
TNAU Coimbtore	**60**	**25**	**856**	**302**	**2600**	**3260**

Among the various constraints quoted above poor and inefficient water management, improper plant protection and poor fertigation practices contributes more

Benefits of premonsoon cotton sowing : Early sowing / planting of cotton isimportatnt for a no. of reasons.it makes possible the most efficient use of precipitation whether stored in the soil or occuring during cotton growth. flowering& boll formation (first flush particularly) occur before month of september. Cotton matures before on set of cold temperatures, detrimental to boll bursting and the boll maturation period becomes longer Delayed sowing results in delayed flowering and this reduces flower and number of bolls. Boll size also reduces. Early sowing (pre monsoon) cotton get better quality, weight of bolls.

Planting time has high importance in irrigated cotton cultivation. Delayed planting reduces the yield (20-25 per cent). The crop suffers from pest attack as well. Importance of timely sowing has been successfully proved in various Agricultural Universities in India. High Temperature in may favors better root penetration being Tap Root in cotton, uniform stand with 95 per cent germination on drip .

Importance of water management :

- Water stress results in withering of leaves n turns to yellow, reduction of leaf area. Affects photosynthesis.
- Water stress affects uptake of nutrients, results in poor growth, reduction in leaf area, squares, flowers n boll size, boll development.
- Dropping of squares n flowers.
- Affect boll weight, reduces yield drastically.

Installation of drip irrigation system in cotton : After careful survey and technical design drip system should be installed in field, prior that better land preparation should be done by use of rotavator, soil should be bring at fine tilth. Performance of drip system depends up on selection of proper filtration system. Filter is the heart of drip system, According to water source and water quality filters should be selected. If water source is deep bore well or river and sand or silt particles are comimg with water then Sand seperator or hydrocyclon filter should be selected, If water source is stagnated water, reservoir, farm pond and algae, clay particles are coming with water then sand filter should be selected, if only physical impurities are coming with water then only screen or disk filter should be selected.. Cotton is close spaced crop and hence inline drip lines should be selected, Jain Turbo Excel, Jain Turbolinesuper,Jain Turbo slim, Jain Polyslim can be used. Spacing between two inline driplines should be 1.2 to 1.5 meter, dripper to dripper spacing should be 40 – 60 cm, dripper discharge should be 2.4 – 4 LPH depend up on soil type,.For fertigation Venturi or fertilizer tank should be installed.

Benefits of adoption of drip irrigation in cotton :

- Drip irrigation saves 50-60 per cent water in cotton. Better utilization of every drop of water.
- Drip Irrigation increase yield minimum by 50 per cent. Farmers experienced more than300 per centSaving of fertilizer by 25 to 30 per cent, can be

possible, water soluble fertilizers can be use with dripsystem.

- Drip irrigation save time, labour,electricity
- Drip irrigation is the best solution in the problem of electricity.
- Drip Irrigation minimises the weed problem.
- Drip Irrigation maintains field capacity all the time, drip irrigationprevents dropping of square,flower and bolls.
- Better development of bolls size.

Yield under Drip irrigation :

Seed cotton yield q/ac	Seed cotton yield q/ha	Lint yield (kg/ha)
8.65 World's yield	21.37	748
12 q/ac Farmer's yield under drip	29.64	1050
15	37.05	1297
16	39.52	1383
20	49.50	1729
25	61.75	2161
30	74.10	2593
44.5	111.15	3847
49.33 Q/ac World's highest yield	121.84	4265

- Drip fertigation improves boll size and weight.
- Crop do not get water stress at any growth stages..

Irrigation scheduling for drip irrigated cotton crop -

Month	Water requirement (L/day/Plant)
May (Planting)	1.132
June	1.6
July	2.21
August	3.605
September	5.5
October	7.1
November	4.75
December	3.26
January	3.31
February	3.61

Note :Above irrigation scheduling is just for guidelines only. It will vary from area to area soil type, climatic conditions, crop growth stage etc.

Fertigation : Nutrition is a backbone of crop production. Normally fertilizers are being used as broadcasting, Drilling, placement ina traditional method, fertilizers are also applied in to 2 – 4 doses in entire crop duration, also not applied as per crop growth phases, in traditional method of fertilizers application fertilizer use efficiency is just 40 – 50 per cent. Due to Leaching, volatilization, fixation fertigation is the best technology to overcome these problems. Fertilizers can be applied daily or alternate days, Nutrients can be applied as per crop growth stages in entire crop period. Application of water soluble fertilizers with drip irrigation technology is known as fertigation. Results of fertigation in cotton are excellent.

Fertigation schedule for cotton

Period of application (Days)	Grade to be used	Qty. required kg/ac	Application kg/ac/ 4th day
7 - 22	12:61:0 +	8.33	1.665
	Urea	10.00	1.998
23 - 60	Urea+	40.72	3.300
	12:61:0 +	26.22	2.124
	MOP	10.36	0.840
61 - 100	Urea+	45.00	3.375
	12:61:0	12.00	0.900
	MOP	13.36	1.002
101-125	MOP+	19.70	2.364
	Urea	20.00	2.400

Note :Above fertigation schedule is for guidelines, it may change according to soil analysis, soil type, crop growth stages, local conditions etc.

• Basal dose before sowing of seeds should be used – 10 : 26 : 26 – 25 kg/ac

Magnesium sulphate – 15 kg/ac
Zinc sulphate – 5 kg/ac
Ferrous sulphate – 5 kg/ac
Borax - 2 kg/ac

Fertigation equipments – soluble fertilizers like Urea, White Potash, 12:61:0, Phosphoric Acid, 19:19:19, 0:52:34,13:40:13, 0:0:50, 13:0:45 can be used with Fertilizer Tank or Venturi injector.

World's highest cotton yield - Success story

- Name of farmer - Shri Narayan Ramchandra Thakur
- Village – Mohide (Mamache) Tal – Shahada, Dist – Nandurbar (MS)
- Land area – 5 ac, soil – heavy, water source – bore
- Cotton Area - 5 ac, variety – RCH – 659
- Spacing –1,98 x 0.30m, plant population - 7260/ac
- Date of planting – 20th May
- Drip irrigation – Jain Inline 20 mm, 40

cm, 4 LPH

- Fertigation - Venturi
- Basal dose – FYM – 2 trollis, 10 :26:26 – 1 bag + Sec n micro nutrients (25 kg bag)
- Biofertilizers – Azatobacter, PSB, KSB + *Trichoderma* with drip system
- Fertigation - Urea, White MOP, 19:19:19, 12:61:0, 13:0:45, 0:52:34, Calcium nitrate
- Hormones – Planofix, Chamatkar
- Foliar feeding – WSF 1 kg packing above grades
- Water management - by Jain drip only
- Staking – Bamboos n nylon thread
- Plant protections – 12 sprays (8 + 4)
- Number of pickings - (6 + 4)
- Yield (Seed cotton) – Main crop – 172q + Reflush - 74.65 q
- Total – 246.65q in 5 ac– 49.33 q/ac

This year also he has harvested bumper yield of seed cotton 22.00 q/ha *i.e.* 55 q/ha without reflush / extended crop due to heavy incidence of cotton pink boll worm

Cost of cultivation of cotton – Area 1 ac (0.40 ha)

Sr. No.	Items/ Description	Rain fed Cotton	Flood irrigated	Drip Irrigated
1	Spacing	1.35 x 0.40 m	1.5 x 0.50 m	1.5 x 0.50 m
2	Seed rate g /ac	650 g	650 g	650 g
3	Land preparation cost / ac (ploughing, harrowing, rotavator)	1500	2000	2000
4	FYM cost / ac		3000	5000
5	Drip cost / ac /season including depreciation, bank interest and maintenance / irrigation charges		2500	5290
6	Seed cost Rs/ac	1300	1300	1300
7	Fertilizers (basal dose)	3000	5000	1500
8	Fertilizers (through fertigation)			7000
9	Plant protection	3000	5000	6500
9	Weeding	2000	3000	3000
10	Labour (pickings)	3000	5000	11000
11	Total cost of cultivation/ac	13800	27800	37000
12	Av. yield with drip (q/ac)	4	10	22
13	Av. Rate Rs/q	5000	5000	5000
14	Gross income Rs/ac	20000	50000	110000
15	Net income Rs/ac	7200	22200	73000

(*Pectinophera gossipiella*) Due to PBW cotton yield are reduced drastically by 40 – 45 per cent. Hence restricted reflush crop of cotton. This year he has not used staking of bamboos.

CONCLUSION

Its true, cotton is a cash crop however yields of cotton under rainfed condition and flood irrigation are low n unsatisfactory, hence net income from cotton to farmers getting less. Drip irrigation has proved in improvement in cotton yields, Shri Narayan Ramchandra Thakur has harvested world's highest yield of cotton 121.85 q/ha (49.33 q/ac). This year he has harvested seedcotton yield 55 q/ha. Under flood irrigation Cotton yield is 10 q/ac and farmers are earning Rs 22200/ac net income and under Jain drip irrigation Shri Narayan Thakur has harvested seed Cotton yield 22 q/ac and earned Rs 73000/ ac net income. Cotton yields underdrip irrigation are more than world's and country's productivity. Hence in Maharashtra adoption of drip irrigation in cotton is highest among all crops. By the adoption of drip irrigation and fertigation farmers are getting bumper yields of Cotton and earning good economical returns.

Hence, Adoption of drip irrigation, fertigation helping Cotton farmers doubling their farm income.

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Evaluation of high density planting system and fertilizer requirement for *hirsutum* cotton varieties

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ABSTRACT : A field experiment was conducted for three years during *kharif* (2014 to 2016) at Main Cotton Research Station, Surat. The experiment was laid out in factorial randomized block design with 18 treatment combination replicated three times. The treatments comprised of three planting density *viz.*, D_1: 120 x 45 cm (18518 plants/ha), D_2: 60 x 15 cm (66667 plants/ha) and D_3: 45 x 15 cm (148148 plants/ha), two varieties, V_1: GSHV-01/1338 and V_2: GBHV-164 and three nitrogen levels, N_1: (100 % RDN) (180 kg/ha), N_2: (125 % RDN) (225 kg/ha) and N_3 : (150% RDN) (270 kg/ha). The N fertilizer in the form of urea was applied in five equal splits at 30, 60, 75, 90 and 105 DAS.

The three years pooled results indicated that the planting density (D_1) recorded significantly higher plant height (118.9 cm) as compared to D_3 (114.5 cm). Among varieties higher plant recorded in V_2 was 119.3 cm as compared to V_1 (114.8 cm). In case of sympodia / plant, interaction of plant density (D) x variety (V), treatment combinations D_2V_1 and D_1V_2, both recording same sympodia / plant (23.3) was found significantly higher over D_3V_1 (21.6). Significant higher bolls was recorded in recommended planting density, D_1 (120 x 45 cm) as compared to closer spacing D_2 (60 x 15 cm) and D_3 (45 x 15 cm). Interaction, D_1V_2 *i.e.*, 120 x 45 cm spacing and variety V_2 (GBHV-164) recorded higher bolls / plant. Among N levels, significant higher bolls / plant was recorded in N_2 (16.6) as compared to N_1 (15.7), however it was found *at par* with N_3 (16.5). Treatment combinations D_1N_2 (36.4) and D_1N_3 (36.0) being *at par* with each other, both recorded significant higher bolls / plant over rest of the treatment combinations. Planting density, D_3 recorded significantly superior boll weight of 2.70 g as compared to D_3 (2.54 g) however, it was found *at par* with D_2 (2.67 g). Both these treatments, D_1V_2 (2.78 g) and D-$_2V_1$ (2.75 g) being *at par* with each other, recorded significant higher boll weight compared to rest of the treatments. The seed cotton yield recorded in D_2 and D_3 were 2125 and 2195 kg/ha, respectively which were significantly higher over D_1 (1729 kg/ha). Significant higher seed cotton yield recorded in V_2 was 2110 kg/ha as against 1921 kg/ha in V_1. N_3 recorded significant higher seed cotton yield (2083 kg/ha) over N_1 (1921 kg/ha) it was found *at par* with N_2 (2045 kg/ha). From the above three years experimental results it can be concluded that *hirsutum* cotton of compact culture type can be preferred under high density planting system. The spacing adopted should be 60 x 15 cm with application of 225 kg nitrogen/ ha in five equal splits at 30, 60. 75, 90 and 105 DAS. By following HDPS, higher yield and net income can be realized as compared to normal method of planting system (120 x 45 cm spacing with application of 180 kg N/ha and).

Cotton is an important commercial crop of India grown for fibre, fuel and edible oil and plays an important role in Indian economy. During recent three years (2014-2015 to 2016-2017) in Gujarat, the average area under cotton is 27.5 lakh ha (Anonymous 2017). The research related to increase production is continuing in India through development of new varieties and hybrids including *Bt* cotton, crop production technologies though increased input use efficiency, better irrigation management practices like drip and pest and disease control. After long a research, potential genotypes and hybrids along with optimum plant population, ideal fertilizer application, crop protection techniques, have played an important role in increasing the seed cotton production in Gujarat and India. The average Gujarat state seed cotton yield / hectare has been stagnating around 650 kg/ha and is still lower as compared to USA and other countries like China and Brazil.

Manipulation of planting density, plant population and spatial arrangement of cotton plants continues to be topics of cotton research worldwide and India is no exception. Studies in number of countries have shown that increasing planting density is an option to increase yield or profits as well as improve input use efficiency (Atwell *et al.*, 1996 and Ali *et al.*, 2010). Research under high density planting (HDP) of cotton has indicated improvement of plant architecture increases sunlight interception, boll load and lint yield of cotton (Reta-Sanchez and Fowler, 2002). Adoption of HDP, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yields. Of the fertilizers, nitrogen management is an important aspect for cotton production under HDP because excessive nitrogen may lead to rank growth and defoliation difficulties whereas insufficient nitrogen may decrease yields (Rinehardt *et al.*, 2003). Several studies have shown mixed response of cotton production with incremental application of nitrogenous fertilizer. McConnell *et al.,* (2008) reported that fertilization with more than 56 kg/ha did not significantly yield. Clawson *et al.* (2006) found a significant increase in lint yield with each 50 kg/ha increase in nitrogen from 0 to 151 kg/ha although the magnitude of the increase was less with each additional increment of nitrogen. The fields were depleted of nitrogen in the year prior to initiation of the study by producing grain sorghum in the test field. The nitrogen requirements for closed spaced cotton were not lower than wider spaced cotton. The inconsistent responses of HDP cotton to changes in nitrogen rate indicate that specific nitrogen rate recommendations need to be more precisely defined.

In view to the above research findings, an experiment was planned to study the effect of HDP along with nitrogen fertilizer on yield and economic feasibility of *hirsutum* cotton varieties of compact genotypes under south Gujarat conditions.

MATERIALS AND METHODS

The experiment was conducted at Main Cotton Research Station, Navsari Agricultural University, Surat (Gujarat) for three years (2014-2015, 2015-2016 and 2016-2017). The experiment was laid in factorial randomized block design with treatments involving three plant density, of which normal recommended spacing of 120 x 45 cm (D_1) was compared with two HDP at 45 x 15 cm (D_2) and 60 x 15 cm (D_3). The varieties selected were compact genotypes of *hirsutum* types, GSHV-01/1338 (V_1) and GBHV-164 (V_2). The nitrogen fertilizer treatments included were 100 per cent of recommended N level *i.e.*, 180 kg/ha which was compared with (125%) (225 kg/ha) and (150 %) (270 kg ha^{-1}) of recommended N level. The N fertilizer treatments were applied in five equal splits at 30, 60, 75, 90 and 105 days after sowing. In all there were 18 treatment combinations with each treatment replicated three times. The crop was sown during *kharif* season with the onset of monsoon during June month.

The soil of the experimental site is deep black, alkaline in reaction, non-saline and clayey in texture. The initial fertility level of the soil was medium in available N and available P_2O_5 content and high in available K_2O content. Operations such as interculturing, irrigation along with pest and disease management were taken care as and when required. The biometric observations *viz.*, plant height, sympodia / plant, bolls / plant, average boll weight and seed cotton yield was recorded at harvest. The year wise biometric observations were statistically analyzed as / standard procedure mentioned by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Growth attributes : The results pertaining to growth parameters (pooled over three years) *viz.,* plant height and sympodia / plant as influenced by spacing, varieties and nitrogen levels is given in Table 1.

Table 1. Effect of plant density, varieties and nitrogen on growth attributing characters

Plant density	Variety		Nitrogen levels			**Mean**
	V_1	V_2	N_1	N_2	N_3	
Plant height (cm)						
D_1	117	121	118	119	120	**119**
D_2	116	119	113	118	122	**118**
D_3	112	117	115	114	115	**115**
Mean	**115**	**119**	**115**	**117**	**119**	**117**
	D	**V**	**D x V**	**N**	**D x N**	**D x V x N**
SEm±	1.02	0.84	1.45	1.02	1.77	**2.51**
CD (0.05)	2.9	2.3	NS	NS	NS	**NS**
CV (per cent)	6.43					
Sympodia/plant						
D_1	23.0	23.3	22.3	23.4	22.2	**22.6**
D_2	23.3	22.6	23.1	22.3	22.1	**22.5**
D_3	21.6	23.0	23.9	23.2	22.5	**23.2**
Mean	**22.6**	**23.0**	**23.1**	**22.9**	**22.3**	**22.8**
	D	**V**	**D x V**	**N**	**D x N**	**D x V x N**
SEm±	0.26	0.21	0.37	0.26	0.45	**0.64**
CD (0.05)	NS	NS	1.0	NS	NS	**NS**
CV (per cent)	8.39					

Plant height (cm) : Plant density and variety effect was found significant on plant height. Planting at normal spacing D_1 (120 x 45 cm) recorded significant higher plant height (119 cm) as compared to closer spacing of D_3 (115 cm), however it was found statistically *at par* with D_2 (118 cm). Similar findings have been reported by Fowler and Ray (1977), Clawson *et al.* (2006) and Jahedi *et al.*, (2013) where wider spaced cotton gave higher plant height as compared to closer spaced cotton.

Among the two varieties, plant height differed significantly where V_2 recorded higher value of 119 as compared to V_1 (115 cm). The interaction of spacing and variety failed to exert any significant difference on plant height.

In case of effect of nitrogen levels, it was found non-significant on plant height. Similarly, interaction effect spacing and nitrogen as well as spacing with varieties and nitrogen levels did not produce any significant effect on plant height. Similarly, Boquet (2005) also observed no affect of nitrogen rate on plant height.

Sympodia/plant: The sympodial branches / plant was not significantly affected by either by individual effect of different plant density, varieties and nitrogen levels. However, the interaction between effect of plant density and varieties turned out to produce significant effect on sympodial branches / plant. Interaction of D_1V_2 and D_2V_1 both recording same sympodial branches / plant (23.3) gave significant higher value as compared to D_3V_1 (21.6) only, while they were *at par* with rest of the treatment combinations.

With respect to nitrogen and its interactions with spacing and all three combinations (D x V x N) had non significant effect sympodial branches / plant.

Yield attributes : The yield attributes *viz.*, bolls / plant and average boll weight (pooled over three years) as affected by different plant density, varieties and nitrogen levels is given in Table 2.

Bolls / square meter: The effect of plant density and variety was found significant on bolls/sqm. Significant higher bolls / sqm was recorded in higher density cotton crop, D_2 (83.8) and D_3 (89.7) as compared to lower density cotton crop D_1. Further, D_3 also excelled significant higher bolls / sqm as compared to D_2. Although, closed spaced cotton plants retained fewer bolls than conventionally planted cotton, but the former retained higher total bolls / sqm. Similar findings have been reported by Darawsheh *et al.,* (2009) and Vories and Glover (2006).

Among the varieties, GBHV-164 (V_2) recorded significant higher bolls / sqm (82.2) as compared to GSHV-01/1338 (V_1) recording 77.0 bolls / sqm. This might be attributed to better adaptability of V_2 in terms of HDP. Similarly, Venugopalan *et al.,* (2013) also noticed such difference among different genotypes planted under HDPS. They reported that, the variation in different genotypes might be due to morphological features, earliness, tolerance to sucking pests and boll weight.

Although the individual factors spacing and varieties were found to have significant effect of bolls / sqm, their interaction turned out to be non-significant.

Among nitrogen levels, treatment N_2 (16.6) recorded significant higher bolls / plant

Table 2. Effect of plant density, varieties and nitrogen on yield attributing characters

Plant density	Variety		Nitrogen levels			**Mean**
	V_1	V_2	N_1	N_2	N_3	
Bolls/sqm						
D_1	63.0	67.7	62.0	67.3	66.7	**65.3**
D_2	82.6	84.9	84.7	83.1	83.4	**83.8**
D_3	85.3	94.1	89.2	89.8	90.0	**89.7**
Mean	**77.0**	**82.2**	**78.6**	**80.1**	**80.0**	**79.6**
	D	**V**	**D x V**	**N**	**D x N**	**D x V x N**
SEm±	1.21	0.99	1.71	1.21	2.10	**2.99**
CD (0.05)	3.39	2.77	NS	NS	NS	**NS**
CV (per cent)	11.17					
Average boll weight (g)						
D_1	2.63	2.78	2.74	2.69	2.67	**2.70**
D_2	2.75	2.58	2.59	2.74	2.66	**2.67**
D_3	2.56	2.53	2.47	2.59	2.58	**2.54**
Mean	**2.65**	**2.63**	**2.65**	**2.68**	**2.64**	**2.64**
	D	**V**	**D x V**	**N**	**D x N**	**D x V x N**
SEm±	0.03	0.03	0.05	0.03	0.06	**0.08**
CD (0.05)	0.09	NS	0.12	NS	NS	**NS**
CV (per cent)	8.77					

as compared to N_1 (15.7), however it was found *at par* with N_3 (16.5). Among the interaction effects of S x N, treatments S_1N_2 (36.4) and S_1N_3 (36.0) being *at par* with each other, both recorded significantly higher bolls / plant compared to rest of the treatment combinations.

Average boll weight/plant : The data pertaining to average boll weight is concerned, the effect of plant density was found to influence it significantly. The higher average boll weight was noticed in lower density cotton crop, D_1 (2.70 g) as compared to higher density cotton crop D_3 (2.54 g), however it was found *at par* with D_2 (2.67 g). These results are in confirmation with the findings of Hussain *et al.,* (2000) who reported that wider spacing increased average boll weight. Ramzan-Ali Alitabar *et al.,* (2013) also found maximum average boll weight with normal spacing as compared to closer spacing.

The effect was variety on average boll weight was found non significant. The average boll weight recorded for variety V_1 (GSHV-01/1338) and V_2 (GBHV-164) were 2.65 g and 2.63 g, respectively. Interaction effect of DxV was also found to affect the average boll weight / plant significantly. The higher average boll weight / plant was observed in treatment combination D_1V_2 (2.78 g) followed by D_2V_1 (2.75 g) both being *at par* with each other recorded significantly higher values as compared to rest of the treatment combinations. The significant differences among varieties for average boll weight had been reported by Hofs *et al.* (2006) that was in contrast to the finding of this experiment. Ali Alitabar (2013) also observed no significant in boll weight among the different varieties.

The effect of N as well as its interaction effect with spacing and its combination with spacing and variety was found non-significant on average boll weight / plant.

Seed cotton yield (kg/ha) : The three years and pooled result of seed cotton yield as influenced by different treatments is given in Table 3.

Effect of spacing: During all the three years of experiment as well as in pooled results, higher density cotton crop planted at 60 x 15 (D_2) and 45 x 15 (D_3) produced significant higher seed cotton yield as compared to cotton crop of lower density *i.e.*, 120 x 45 cm (D_1). In pooled results, the seed cotton yield recorded in D_2 and D_3 were 2125 and 2195 kg/ha, respectively which were significantly higher over D_1 (1729 kg/ha). Higher seed cotton yield with narrow plant spacing was the direct result of higher plant density compared to wider row spacing in spite of having more bolls / plant. This higher plant density with narrow plant spacing had 23 (60 x 15 cm) and 43 / cent (45 x 15 cm) more bolls / square meter as compared to normal spaced crop (120 x 45 cm). Venugopalan *et al.,* (2011) also reported that closer spaced cotton (45x13.5 cm) gave 38 / cent higher seed cotton yield than that obtained with the recommended (60x30 cm spacing). Brodrick *et al.* (2012) reported that reduction in spacing between rows promote the increase in the yield of cotton seed. Nehra and Yadav (2012) reported that the increase in yield was attributed to increased plant population under narrow spacing.

Table 3. Effect of plant density, varieties and nitrogen levels on seed cotton yield (kg/ha)

Treatment	Seed cotton yield (kg/ha)			
	2013-2014	2014-2015	2015-2016	**Pooled**
Plant density (D)				
D_1 (18518 plants/ha)	1470	2228	1489	**1729**
D_2 (66667 plants/ha)	1824	2556	1995	**2125**
D_3 (148148 plants/ha)	1974	2537	2073	**2195**
SEm±	58.519	55.165	37.992	**30.133**
CD (0.05)	168	159	105	**85**
Variety (V)				
V_1 : GISV-01/1338	1693	2334	1740	**1923**
V_2 : GBHV-164	1819	2546	1964	**2110**
SEm±	47.780	45.042	31.021	**24.604**
CD (0.05)	NS	130	86	**69**
Nitrogen (N)				
N_1 : 100 per cent RDN (180 kg/ha)	1695	2344	1724	**1921**
N_2 : 125 per cent RDN (225 kg/ha)	1809	2466	1859	**2045**
N_3 : 150 per cent RDN (270 kg/ha)	1763	2511	1974	**2083**
SEm±	58.519	58.519	37.992	**30.133**
CD (0.05)	NS	NS	105	**85**
Mean	**1756**	**2440**	**1852**	**2016**
Interaction	NS	DV	DV & VN	**Y, YDV, YVN**
CV (per cent)	14.14	9.59	8.70	**10.98**

Effect of varieties : Significant difference in seed cotton yield was recorded among the two varieties during 2[nd], 3[rd] and in pooled results. Variety GBHV-164 (V_2) recorded significant higher seed cotton yield as compared to GISV-01/1338 (V_1) during 2[nd] and 3[rd] year as well as in pooled result. In pooled result, significant higher seed cotton yield recorded in V_2 (2110 kg/ha) as against V_1 (1923 kg/ha).

Effect of nitrogen levels: Among the individual years, the influence of N levels on seed cotton yield was found significant only during 3[rd] year. Nitrogen level, N_3 recorded significant higher seed cotton yield (1974 kg/ha) as compared to both N_1 (1724 kg/ha) and N_2 (1859 kg/ha). However, in pooled results, although N_3 recorded significant higher seed cotton yield (2083 kg/ha) over N_1 (1921 kg/ha) but was found *at par* with N_2 (2045 kg/ha). The increase in seed cotton yield with higher nitrogen level might be due to more photosynthetic activity which resulted in more dry matter accumulation. Gadade *et al.,* (2015) reported that seed cotton yield increased with increasing levels of fertilizer up to 125 / cent RDF (75:37.5:37.5 NPK kg/ha).

Table 4 Interaction effect of plant density (D) and variety (V) on seed cotton yield

Treatment	2013-2014			2014-2015			2015-2016			**Pooled**		
	V_1	V_2	**Mean**	V_1	V_2	**Mean**	V_1	V_2	**Mean**	V_1	V_2	**Mean**
D_1	1391	1550	**1470**	1951	2505	**2228**	1441	1537	**1489**	**1594**	**1864**	**1729**
D_2	1777	1870	**1824**	2536	2575	**2556**	1952	2038	**1995**	**2088**	**2161**	**2125**
D_3	1910	2037	**1974**	2515	2559	**2537**	1829	2317	**2073**	**2085**	**2304**	**2195**
Mean	**1693**	**1819**	**1756**	**2334**	**2546**	**2440**	**1740**	**1964**	**1852**	**1923**	**2110**	**2016**
D x V												
SEm±	82.758	78.015	53.729	52.615								
CD (0.05)	NS	224	149	NS								
Y x D x V												
SEm±	73.811											
CD (0.05)	207											

Similarly, Multi–location trails were conducted under Technology Mission on Cotton have indicated that under narrow spacing 125 per cent of fertilizer requirement was found optimum for getting higher seed cotton yield (Singh *et al.*, 2012). Nehra and Yadav (2012) also found increased seed cotton yield with higher application of fertilizers (N and K), however they found non significant difference.

Interaction effect of spacing (D) and variety (V): The interaction effect of plant density and variety on seed cotton yield was found significant during 2[nd] (2014-2015) and 3[rd] (2015-2016) of the experiment (Table 4). During 2014-2015, significant higher seed cotton yield was recorded in D_2V_2 (2559 kg/ha) as compared to S_1V_1 (1951 kg/ha), while it was *at par* with rest of the treatments. During 2015-2016 treatment D_2V_2 recorded significant higher seed cotton yield of 2304 kg/ha as compared to rest of the treatments. The interaction of YxDxV was also found significant, where during 2014-2015 the significant higher seed cotton yield recorded

Table 5. Interaction effect of variety (V) and nitrogen levels (N) on seed cotton yield

Treatment	2013-2014				2014-2015				2015-2016				**Pooled**			
	N_1	N_2	N_3	**Mean**	N_1	N_2	N_3	**Mean**	N_1	N_2	N_3	**Mean**	$\mathbf{N_1}$	$\mathbf{N_2}$	$\mathbf{N_3}$	**Mean**
$\mathbf{V_1}$	1608	1754	1715	**1693**	2147	2393	2463	**2334**	1659	1831	1731	**1740**	1805	1993	1970	**1923**
$\mathbf{V_2}$	1781	1865	1811	**1819**	2541	2539	2558	**2546**	1788	1887	2216	**1964**	2037	2097	2195	**2110**
Mean	**1695**	**1809**	**1763**	**1756**	**2344**	**2466**	**2511**	**2440**	**1724**	**1859**	**1974**	**1852**	**1921**	**2045**	**2083**	**2016**
V x N																
SEm±	82.758	78.015	53.729	42.615												
CD (0.05)	NS	NS	149	NS												
Y x V x N																
SEm±	73.811															
CD (0.05)	207															

(2440 kg/ha) over rest of the years. Significant interaction between genotypes and spacing was also reported by Rossi *et al.,* (2007) and Venugopalan *et al.,* (2011).

Interaction effect of variety (V) and nitrogen levels (N): The interaction effect of variety and nitrogen was found significant on seed cotton yield only during 2015-2016 (Table 5). Treatment V_2N_3 recorded significant higher seed cotton yield (2216 kg/ha) as compared to V_1N_1 (1659 kg/ha), V_2N_1 (1788 kg/ha) and V_1N_3 (1731 kg/ha). The year effect for V x N was also found significant on seed cotton yield with highest value recorded during 2014-2015 (2440 kg/ha).

Cost economics : Since the interaction effect of spacing, variety and nitrogen levels on seed cotton yield was found to be non significant, the cost economics was calculated on individual treatment basis (Table 6). Among the plant density treatments, D_3 had the highest gross income (Rs. 109730/ha), net income (Rs.59806/

Table 6. Cost economics of different treatments

Treatment	Seed cotton yield (kg/ha)	Total cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	BCR
Plant density (D)					
$\mathbf{D_1}$ (18518 plants/ha)	1729	44986	86449	41463	1.92
$\mathbf{D_2}$ (66667 plants/ha)	2125	49064	106231	57167	2.17
$\mathbf{D_3}$ (148148 plants/ha)	2195	49924	109730	59806	2.20
Variety (V)					
$\mathbf{V_1}$ (GSHV-01/1338)	1923	47524	96125	48602	2.02
$\mathbf{V_2}$ (GBHV- 164)	2110	48459	105481	57022	2.18
Nitrogen (N)					
$\mathbf{N_1}$ (180 kg/ha)	1921	46901	96044	49142	2.05
$\mathbf{N_2}$ (225 kg/ha)	2045	48135	102237	54102	2.12
$\mathbf{N_3}$ (270 kg/ha)	2083	48938	104129	55191	2.13

**Selling price of cotton @ Rs.50/kg*

ha) and BCR (2.20) which was closely followed by D_2 treatment with gross amount of Rs.106231, net income of Rs.57167 and BCR (2.17). Among the varieties, the higher gross income (Rs.105481/ha), net income (57022) and BCR (2.18) was realized from V_2. In case of N levels, although N_3 had higher gross return (Rs.104129/ha), net income (Rs.55191/ha) and BCR (2.13) it was closely followed by N_2 with gross income, net income and BCR of Rs.102237/ha, 54102/ha and 2.12, respectively.

CONCLUSION

Hirsutum cotton of compact culture type can be preferred under high density planting system. The spacing adopted should be 60 cm x 15 cm with application of 225 kg nitrogen/ ha in five equal splits at 30, 60. 75, 90 and 105 DAS. By following HDP, higher yield and net income can be realized as compared to normal method of planting system (120 x 45 cm spacing with application of 180 kg N/ha).

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Cotton production technologies of newly developed *hirsutum* and *arboreum* genotypes through HDPS under irrigated condition

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ABSTRACT : A field experiment was conducted for initial evaluation of twenty compact cotton genotypes of *G. hirsutum* along with two checks to evaluate the effect of HDPS and varieties for yield and quality parameters at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during 2016-17. The experiment was laid out in completely randomized block design with three replications. The results of the experiment indicated that seed cotton yield of different genotypes found statistically significant and ranges from 3370 kg/ha to 6193 kg/ha. The genotype RHC-HD-1420 (6193 kg/ha) showed significantly superior over the best check Phule Yamuna (4781 kg/ha) at closer spacing for seed cotton yield. Whereas, five genotypes viz. RHC-HD-1312 (5623 kg/ ha), RHC-HD-1433 (5399 kg/ha), RHC-HD-1446 (5336 kg/ha), RHC-HD-1438 (5187 kg/ha) and RHC-HD-1430 (5176 kg/ha) showed numerical higher yield over best check Phule Yamuna. The highest ginning percentage was recorded by the strain RHC-HD-1427 (38.9%) followed by RHC-HD-1433 (38.0 per cent), RHC-HD-1412 (37.6%), RHC-HD-1420 and RHC-HD-1425 (36.0%). Regarding *arboreum* cotton, field experiment was conducted at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri to find out the optimum spacing for growth and yield of cotton variety Phule Dhanwantary with nine spacings in randomised block design during 2016-2017 to 2018-2019. The experimental findings revealed that *deshi* cotton variety Phule Dhanwantary planted at distance 45 cm x 15 cm recorded higher seed cotton yield (18.30 q/ha) with higher gross monetary returns, net monetary returns and B:C ratio than all other spacing's.

***Key words** :* Compact genotype, *G. hirsutum* , *G. arboreum*, HDPS

India has the largest area in the world under cotton at 12.250 m ha and is the second largest producer in the world with 27.00 m bales. However, India's average cotton productivity is 480 lint yield kg/ha combining both irrigated and rainfed fields and this is low compared to other countries like China (1726) , Brazil (1636), United States (936) and the World average yield was (779) lint yield kg/ha (Anonymous, 2018-2019).

The Ultra Narrow Row system is popular in several countries like Brazil, China, Australia, Spain, Uzbekistan, Argentina, USA and Greece (Rossi *et. al.,* 2004). The availability of compact genotypes, acceptance of weed and pest management technologies including transgenics, development of stripper harvesting machines and widespread application of growth regulators have made these high density cotton production systems successful in these countries. The obvious advantage of this system is earliness (Rossi *et. al.,* 2004) since Ultra Narrow Row needs less bolls / plant to achieve the same yield as conventional cotton and the crop does not have to maintain the late formed bolls to mature. The ultra narrow row system cotton plants produce fewer bolls than conventionally planted cotton but retain a higher percentage of the total bolls in the first sympodial position and a lower percentage in the second position (Vories and Glover, 2006).The other advantages include better light interception, efficient leaf area development and early canopy closure which will shade out the weeds and reduce their competitiveness (Wright *et. al.,* 2011). The early maturity in soils that do not support excessive vegetative growth (Jost and Cothern, 2001) can make this system ideal for shallow to medium soils under rainfed conditions, where conventional late maturity hybrids experience terminal drought. Therefore, the high density planting system (HDPS) is now being conceived as an alternate production system having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India.

MATERIALS AND METHODS

***Hirsutum* genotypes :** The work was initiated during 2012-2013 to develop the suitable *hirsutum* genotypes for high density planting system (HDPS). Efforts were made to develop short (2-3 Feet), zero monopodial, compact, early and synchronous maturing varieties with fruiting bodies close to the main stem. Twenty *hirsutum* genotypes highly resembles to HDPS has been selected from germplasm as well as segregating population. For evaluation of these genotypes a field experiment was conducted in completely randomized block design with three replications at Cotton Improvement Project, MPKV, Rahuri during *kharif* 2016-2017 under irrigated condition. The topography of experimental field was fairly uniform, leveled and with a good drainage. The soil was deep black with rich in nutrients. Two rows of 7.2 m length of each genotype with a spacing of 60 cm x 15 cm were sown. The biometric observations on growth and yield attributes were recorded as per the standard procedure.

***Arboreum* genotype:** This field experiment was conducted at Cotton Improvement Project, M.P.K.V., and Rahuri to find out the optimum spacing for growth and yield of *arborium* cotton variety and also to study the economics of different treatments. The experiment was laid out in Randomized Block Design with three replications on medium deep black cotton soils during 2016-2017, 2017-2018 and 2018-2019. The experiment comprises with nine treatment spacings *viz.,* 45 x 15 cm^2, 45 x 30 cm^2, 45 x 45 cm^2, 60 x 15 cm^2, 60 x 30 cm^2, 60 x 45 cm^2, 90 x 15 cm^2, 90 x 30 cm^2 and 90 x 45 cm^2. The *arboreum* cotton variety Phule Dhanwantary developed by M.P.K.V., Rahuri was tested in the experiment under irrigated condition (Protective irrigation). The experiment was fertilized with 80:40:40 NPK kg/ha having gross plot size 5.40 x 3.60 m^2. The experimental data was statistically analyzed and three years of pooled mean data is used.

RESULTS AND DISCUSSION

***Hirsutum* genotypes:** Data on yield and yield attributes of twenty compact genotypes are presented in Table 1. The mean sum of squares due to treatment for all characters was highly significant except number of monopodia per plant. The genotype RHC HD-1420 recorded significantly higher seed cotton yield (6193 kg/ha) and lint yield (2230 kg/ha) over the best check Phule Yamuna (4781 kg/ha and 1590 kg/ha, respectively). Likewise, this genotype gave significantly higher seed cotton yield per plant (75 g) over the checks (52 g/plant). Among the genotypes five genotypes *viz*., RHC-HD-1430 (5176 kg/ha and 1848 kg/ha), RHC-HD-1433 (5399 kg/ha and 2051 kg/ha), RHC-HD-1438 (5187 kg/ha and 1770 kg/ha), RHC-HD-1446 (5336 kg/ha and 1871 kg/ha) and RHC-HD-1312 (5626 kg/ha and 1931 kg/ha) gave numerical higher seed cotton yield and lint yield over the check. The genotype RHC-HD-1433 gave significantly higher lint yield (2051 kg/ha). Among the genotypes RHC-HD-1502 recorded significantly superior average boll weight (6.0 g) over the check (4.7 g). Most of the genotypes have excellent boll size (>4.5 cm) which shows positive increment in desirable direction. All the genotypes show synchronous maturity and earliness. But still more efforts required to develop extra early maturity i.e. 120-130 DAS genotypes to escape the pink boll worm infestation. Looking to the sympodia per plant, none of the genotypes recorded significantly superior number over the check. However, RHC HD-1420, RHC HD-1446, RHC HD-1312 and RHC HD-1314 recorded higher sympodia/plant.

Ginning percentage, lint index, seed index and fibre quality parameters of twenty genotypes tested in Station trial are presented in Table 2. The superiority of genotypes was varying among the characters. The genotype RHC HD-1427 was superior in ginning percentage while genotype RHC HD-1433 was superior in lint index. Likewise, the genotype RHC HD-1438 showed superior seed index (100 seed weight). The fibre quality parameters were estimated on ICC mode at CIRCOT, Mumbai. All the genotypes showed excellent fibre properties. Staple length ranged from 28.3mm (medium long) to 32.4 mm (Long staple cotton) and tenacity ranged from 19.7g/tex to 24.0 g/tex. Among the genotypes RHC-HD-1405 recorded highest staple length whereas, Phule Yamuna (Check) recorded highest tenacity i.e. 24.0 g/tex. The genotypes RHC-HD-1420 have fine micronaire (3.3).

Among the genotypes studied, the RHC-HD-1420 had significant seed cotton yield, zero monopodial branched, more sympodial branches, highest boll weight with early maturity and hence it would be more desirable for High Density Planting System. Data further indicated that, genotypes RHC-HD-1430, RHC-HD-1433, RHC-HD-1438, RHC-HD-1446 and RHC-HD-1312 responded favorably to HDPS. Silva *et al.* (2002) and Rossi *et al.*, (2007) observed significant interaction between plant density and genotype and recommended a density dependent selection of genotypes.

***Arboreum* genotype:** The experimental data on ancillary observations, seed cotton yield and economics of arboreum cotton *Phule*

Table 1. Seed cotton yield, lint yield and ancillary characters of different entries (*kharif* 2016).

Sr No.	Entry	Yield (kg/ha)		Branches and Bolls/plant (No)			Plant height	Average boll weight (g)	SCY / plant (g)	Days required for 50 per cent	
		Seed Cotton	Lint	Mono	Symp	Bolls				Flow.	Bursting
1	RHC-HD-1405	4728	1556	0.0	12.9	17	116	4.7	51	54	119
2	RHC HD-1406	4689	1616	0.0	11.7	13	105	**5.1**	40	53	**118***
3	RHC HD-1411	4191	1502	0.0	8.9	12	94	4.4	59	54	120
4	RHC HD-1412	4097	1542	0.0	12.2	15	104	4.1	46	53	119
5	RHC HD-1420	**6193***	**2230***	0.0	**15.1**	19	**127***	**5.3**	**75***	55	121
6	RHC HD-1425	4567	1643	0.1	11.1	14	98	3.7	58	54	120
7	RHC HD-1426	4555	1637	0.0	9.8	13	94	4.6	55	53	119
8	RHC-HD-1427	3370	1312	0.0	8.8	12	98	4.4	40	53	**118***
9	RHC-HD-1430	**5176**	**1848**	0.0	10.3	14	102	4.7	54	54	120
10	RHC-HD-1432	4289	1495	0.0	9.8	13	90	4.8	48	53	120
11	RHC-HD-1433	**5399**	**2051***	0.0	12.2	18	102	**5.2**	56	56	122
12	RHC-HD-1434	4517	1608	0.0	11.1	17	102	**5.1**	53	55	121
13	RHC HD-1436	4519	1502	0.0	11.0	14	98	**5.1**	47	55	121
14	RHC HD-1438	**5187**	**1770**	0.0	10.7	15	100	3.7	54	56	122
15	RHC HD-1446	**5336**	**1871**	0.1	**14.9**	**20**	**124***	3.7	60	56	122
16	RHC-HD-1312	**5623**	**1931**	0.1	**13.1**	**20**	112	5.0	**69***	56	123
17	RHC-HD-1314	4757	1504	0.1	**14.4**	19	116	4.2	48	56	121
18	RHC-HD-1333	3847	1311	0.1	10.2	13	100	4.4	40	54	120
19	RHC-HD-1501	4193	1420	0.0	13.9	18	110	**5.1**	41	53	119
20	RHC-HD-1502	4438	1462	0.0	**15.3**	**20**	**119***	**6.0***	40	54	120
21	Phule-688(c)	4680	1473	0.0	11.3	14	109	**5.0**	40	56	121
22	Phule Yamuna (c)	4781	1590	0.1	12.8	17	**118***	4.7	52	53	120
G. Mean		**4688**	**1630**	**-**	**11.9**	**16**	**106**	**4.7**	**52**	**54**	**120**
S.E. (kg/ha) ±		356.29	125.75	-	1.30	1.41	4.19	0.32	5.47	0.33	0.33
C.D. (p=0.05)		1016.86	358.89	*NS*	3.72	4.02	11.97	0.90	15.60	0.94	0.94

Table 2. Ginning percentage, lint index, seed index and fibre quality parameters (*kharif* 2016).

Sr No	Entry	Ginning (%)	Lint index	Seed index	2.5 per cent SL	UR (%)	MIC	Tenacity 3.2 mm g/tex	Elon. (%)
1	RHC-HD-1405	32.9	4.4	9.1	**32.4**	48	4.2	22.8	5.3
2	RHC HD-1406	34.5	5.3	10.2	**31.7**	50	4.0	20.3	6.0
3	RHC HD-1411	35.8	5.9	10.6	29.2	52	4.4	20.5	6.4
4	RHC HD-1412	37.6	5.4	9.0	28.8	49	4.8	19.7	6.6
5	RHC HD-1420	36.0	5.5	9.8	28.3	52	**3.3**	19.7	**6.9**
6	RHC HD-1425	36.0	5.5	9.8	29.6	53	3.8	22.8	6.6
7	RHC HD-1426	35.9	6.1	10.9	29.9	53	4.4	21.0	5.9
8	RHC-HD-1427	**38.9**	5.7	8.9	29.7	50	4.9	20.0	5.9
9	RHC-HD-1430	35.7	5.7	10.2	30.9	52	4.4	20.8	5.9
10	RHC-HD-1432	34.9	5.5	10.3	28.7	53	3.9	22.4	5.9
11	RHC-HD-1433	38.0	**6.4**	10.4	29.9	53	4.0	22.7	5.9
12	RHC-HD-1434	35.6	6.1	11.1	29.4	53	4.3	22.1	5.9
13	RHC HD-1436	33.2	5.4	10.8	29.5	54	4.6	21.8	5.9
14	RHC HD-1438	34.1	6.0	**11.6**	30.7	54	4.4	21.6	5.9
15	RHC HD-1446	35.1	5.2	9.6	28.9	54	5.2	22.4	5.9
16	RHC-HD-1312	34.3	5.2	9.9	29.2	55	4.8	21.0	5.9
17	RHC-HD-1314	31.6	4.2	9.2	28.9	53	4.2	20.9	5.8
18	RHC-HD-1333	34.1	5.1	9.9	29.2	50	3.9	21.2	5.8
19	RHC-HD-1501	33.9	5.7	11.2	30.4	52	5.3	21.7	5.9
20	RHC-HD-1502	33.0	5.4	11.1	**31.7**	51	4.9	22.4	5.9
21	Phule-688(c)	31.5	4.8	10.5	28.3	**56**	4.4	23.3	6.0
22	Phule Yamuna (c)	33.3	4.0	8.1	28.5	54	3.8	**24.0**	6.0

Dhanwantary are presented in Table 3 and 4. Amongst the different spacings, the spacing 45 x 15 cm (S_1) observed significantly maximum plant height (120.74 cm) than other spacing's. However, it was *at par* with spacing 60 x 15 cm (117.68 cm) at harvest. The spacing 90 x 45 cm (S_9) recorded significantly higher bolls/plant (24.37) and average boll weight (4.60 g) than rest of spacing's. The spacing 45 x 15 cm (S_{1} - 1,48,148 plants/ha) recorded significantly higher seed cotton yield (18.30 q/ha) than rest of all other spacing's and also observed 24 per cent higher seed cotton yield than normal spacing of 45 x 30 cm (S_2 - 74,074 plants/ha). The spacing 45 x 15 cm (S_1) recorded highest gross monetary returns (Rs.93,557/ha), net monetary returns (Rs. 39,297/ha) and B:C ratio (1.71) than rest of spacing. Pradeep Kumar *et. al.,* (2017) reported that significantly higher seed cotton yield (2063 kg/ha), gross return (87586/ha), net monetary returns (50031/ha) and B: C ratio (2.33) was recorded at plant spacing of 45 x 15 cm^2 as compared to other spacing's. Similar findings observed by Paslawar *et. al.,* (2015) and Kambe Ashish (2017).

CONCLUSION

It is concluded that the *hirsutum* genotype, the RHC-HD-1420 had significant seed

Table 3. Ancillary observations and seed cotton yield as influenced by different treatments (2016-17 to 2018-19).

Treatments	Pooled mean				
	Plant height (cm)	Bolls/ plant	Average boll weight (g)	Seed cotton yield/plant (g)	Seed cotton yield (q/ha)
S1: 45 x 15 cm^2	120.74	12.91	2.82	34.70	18.30
S2: 45 x 30 cm^2	111.97	19.03	3.42	63.81	14.76
S3: 45 x 45 cm^2	104.55	19.98	4.12	80.25	12.40
S4: 60 x 15 cm^2	117.68	16.50	3.13	48.74	16.27
S5: 60 x 30 cm^2	108.02	21.46	3.87	80.42	13.08
S6: 60 x 45 cm^2	103.30	23.29	4.24	97.67	11.22
S7: 90 x 15 cm^2	109.84	18.27	3.71	65.39	14.16
S8: 90 x 30 cm^2	98.68	22.15	4.36	92.20	10.88
S9: 90 x 45 cm^2	98.25	24.37	4.60	111.12	10.74
S.E. +	**3.04**	**0.99**	**0.18**	**4.51**	**0.67**
C.D.at 5 per cent	**8.69**	**2.01**	**0.51**	**12.74**	**1.89**

Table 4. Economics of different spacings treatments (2016-2017 to 2018-2019).

Treatments	Pooled mean		
	Gross monetary returns/ha (Rs)	Net monetary returns/ha$^-$ (Rs)	B:C ratio
S1: 45 x 15 cm^2	93557	39297	1.71
S2: 45 x 30 cm^2	75564	23212	1.43
S3: 45 x 45 cm^2	63642	12685	1.24
S4: 60 x 15 cm^2	83228	29991	1.56
S5: 60 x 30 cm^2	66976	15620	1.30
S6: 60 x 45 cm^2	57472	7214	1.14
S7: 90 x 15 cm^2	72449	20620	1.39
S8: 90 x 30 cm^2	55810	6032	1.11
S9: 90 x 45 cm^2	55077	5307	1.10
S.E. +	3570	3040	—
C.D. at 5%	10088	8590	—

cotton yield, zero monopodial branched, more sympodial branches, highest boll weight with early maturity and hence it would be more desirable for High Density Planting System.

Regarding *arboreum* cotton, under irrigated condition, planting of Phule Dhanwantary *deshi* cotton variety at 45 cm (row) x 15 cm (plant) is recommended for obtaining higher seed cotton yield and monetary returns for high density planting.

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Influence of high density planting system on weed population in cotton (*Gossypium hirsutum* L.)

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ABSTRACT : A field experiment was conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during *kharif* seasons of 2014 and 2015. The experiment was laid out in factorial randomized block design (control *vs.* rest) involving eight treatment combinations of two plant densities (**D_1**: 2,22,222 plants/ha and **D_2**:1,66,666 plants/ha) and four fertilizer levels (**F_1**:120:00:00:15 $N:P_2O_5:K_2O:ZnSO_4$ kg/ha, **F_2**:120:30:00:15 $N:P_2O_5$: K_2O: $ZnSO_4$ kg/ha, **F_3**:120:00:60:15 $N:P_2O_5:K_2O:ZnSO_4$ kg/ha and **F_4** :120:30:60:15 $N:P_2O_5$: K_2O: $ZnSO_4$ kg/ha) in addition to absolute control treatment (120 x 45 cm spacing with 160-0-0 kg NPK/ha).

The results with respect to weed count (weed plants/m^2) indicated that at 30 days after sowing (DAS) significant higher weed plants (60.1plants/m^2) was recorded in treatment D_2 as compared to 50.7 plants/m^2 in D_1 treatment. Whereas, at 60 DAS, wider spaced crop (D_2) recorded significant higher number of weed plants/m^2 (39.0) as compared to 33.6 plants/m^2 recorded in D_1. Different fertilizer levels as well as interaction effect of plant densities and fertilizer levels (D x F) could not influence significantly on number of weed plants/m^2 at 30 and 60 days after sowing. At both, 30 and 60 DAS, number of weed plants/m^2 recorded in HDPS was significantly lower than control. For Control *vs.* TM, significantly lower number of weed plants/m^2 were recorded in treatment D_1 only as compared to control at 30 and both D_1 and D_2 recorded significantly lower number of weed plants/m^2 than control 60 DAS.

The results pertaining to weed dry weight (g/m^2), closed spaced crop (D_1) recorded significantly lower weed dry weight (31.8 g/m^2) as compared to 37.1 g/m^2 in treatment D_2 at 30 DAS . Weed dry weight recorded in treatment D_2 (19.4 g/m^2) was significantly higher as against 16.7 g/m^2 recorded in treatment D_1 at 60 DAS. Different fertilizer levels did not show significant effect on weed dry weight (g/m^2) at 30 as well as 60 DAS. Interaction effect of plant densities and fertilizer levels (D x F) was found to be non-significant with respect to weed dry weight (g/m^2) for both recorded at 30 and 60 DAS. At 30 DAS, average weed dry weight recorded in HDPS (34.4 g/m^2) was significantly lower than control (40.8 g/ m^2). In case of Control *vs*. TM, treatment D_1 (31.8 g/m^2) and D_2 (37.1 g/ m^2) recorded significantly lower weed dry weight as compared to control (40.8 g/ m^2). Average weed dry weight recorded at 60 DAS in HDPS (18.1g/m^2) was significantly lower than control (26.1 g/m^2) where as in Control *vs* TM, both the tested plant densities (D_1 and D_2) recorded significantly lower weed dry weight than control.

Cotton is one of the most important commercial crops of India. To strengthen the economy of the farmers and the country, it is essential to enhance the productivity of this crop which is governed by many factors. Weed management plays very crucial role because wide spacing, initial slow growth, continuous rainfall and heavy use of nutrients provide enough room for profuse growth of weeds resulting in critical crop-weed competition ultimately in poor seed cotton yield. This competition can be reduced remarkably by adopting suitable weed control measures. Looking to the variety of weed flora, feasibility and conveniency, it is difficult to adopt any single method of weed management thereby emphasizing integrated approach in this regard. Keeping this in view, this experiment was planned to evaluate some pre and post emergence herbicides alone as well as coupled with mechanical methods.

Among the agronomic constraints of cotton production, weed infestations have historically been a major issue. Despite many advances in weed management technology, cotton growers still face significant challenges from weeds.

Studies have demonstrated that cultural crop production practices including row spacing can influence weed-crop interactions and duration of the CPWC. Cotton planted in a narrow row spacing (25 inches) requires a shorter weed-free maintenance period and becomes more competitive with weed flora than cotton planted with a wider row spacing (38-40 inches) Jamshid *et a*l.,(2012).

MATERIALS AND METHODS

A Field experiment was conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during *kharif* seasons of 2014-2015 and 2015-2016. Eight treatment combinations of two plant densities (**D_1**: 2,22,222 plants/ha and **D_2**:1,66,666 plants/ha) and four fertilizer levels (**F_1**:120:00:00:15 $N:P_2O_5:K_2O:ZnSO_4$ kg/ha, **F_2**:120:30:00:15 $N:P_2O_5: K_2O: ZnSO_4$ kg/ha, **F_3**:120:00:60:15 $N:P_2O_5:K_2O:ZnSO_4$ kg/ha and **F_4** :120:30:60:15 $N:P_2O_5: K_2O: ZnSO_4$ kg/ha) in addition to absolute control treatment (120 x 45 cm spacing with 160-0-0 kg NPK/ha) were embedded in factorial randomized block design with three replications. The gross plot size was 7.20 m x 6.3 m where as net plot sizes were 5.4 x 5.3 m for D_1, 4.8 x 5.3 m for D_2 and 4.8 m x 5.4 m for control plot during both the years. Sowing of cotton variety G. Cot. 16 was done on 20th July, 2014 in *kharif*-2014 and 26th June, 2015 in *kharif*-2015 season in each plot, manually as per treatment. All necessary cultural operations were carried out during both the seasons. the weather conditions were normal and congenial for satisfactory growth of cotton crop during both the years.

RESULTS AND DISCUSSION

Effect on weed count : Different plant densities expressed their significant effect on weed count (weed plants/m^2) recorded at 30 and 60 days after sowing. Wider spaced crop (1,66,666 plants/ha) recorded significantly higher weed plants (60.1 plants/m^2 at 30 and 39.0 plants/m^2 at 60 days after sowing) as against narrow spaced crop with

Table 1. Effect of plant density and fertilizer levels on weed count, weed dry weight and seed cotton yield

Treatments	Weed count (plants/m^2) At 30 DAS	Weed count (plants/m^2) At 60 DAS	Weed dry weight (g/m^2) At 30 DAS	Weed dry weight (g/m^2) At 60 DAS	Seed cotton yield(kg/ha)
Plant density (D):					
D_1: 2,22,222 plants/ha	50.7	33.6	31.8	16.7	2321
D_2: 1,66,666 plants/ha	60.1	39.0	37.1	19.4	2112
S. Em. ±	0.87	1.17	0.61	0.51	39.09
CD (p=0.05)	2.5	3.4	1.8	1.5	113.6
Fertilizer levels (F): $N:P_2O_5:K_2O:ZnSO_4$ kg/ha					
F_1 : 120:00:00:15	55.0	36.0	34.7	18.3	2148
F_2 : 120:30:00:15	55.5	36.5	34.2	18.2	2205
F_3 : 120:00:60:15	54.7	35.4	33.9	17.5	2236
F_4 : 120:30:60:15	56.4	37.4	35.0	18.4	2277
S. Em. ±	1.23	1.65	0.86	0.72	55.28
CD (p=0.05)	NS	NS	NS	NS	NS
Interaction (D x F)					
S. Em. ±	1.74	2.34	1.22	1.01	78.18
CD CD (p=0.05)	NS	NS	NS	NS	NS
Mean (T)	**55.4**	**36.3**	**34.4**	**18.1**	**2217**
Control	**62.2**	**47.2**	**40.8**	**26.1**	**1851**
C *vs.* T*					
S. Em. ±	1.69	2.17	1.23	1.03	69.06
CD CD (p=0.05)	4.8	6.2	3.5	2.9	198.5
C vs. TM**					
S. Em. ±	1.27	1.63	0.92	0.77	51.80
CD CD (p=0.05)	3.6	4.7	2.7	2.2	148.9
Year					
S. Em. ±	**0.9**	**1.17**	**0.61**	**0.51**	39.09
CD CD (p=0.05)	2.53	NS	1.8	NS	113.6
CV (per cent)	7.7	15.8	8.7	13.7	8.6

* Control *vs.* Treatment

** Control *vs.* Treatment Mean

DAS = Days after sowing

Control= Recommended spacing (120 x 45 cm) and Fertilizer (160:00:00 kg NPK/ha)

2,22,222 plants/ha (50.7 plants/m^2 at 30 and 33.6 plants/m^2 at 60 days after sowing). The weed plants compete with main crop for natural resources like space, moisture, nutrients and sunlight. Comparatively higher shading effects of crop plants sown at narrow spacing might have reduced the chance of availability of sunlight to the weed plants, necessary for photosynthetic reaction than wider spaced crop. Shading the top soil and competititon for water and nutrients will certainly suppress weed germination and growth (Altieri and Liebman,1986). A previous study demonstrated that cotton planted at high populations was found to be more effective in reducing weeds like sicklepod and pigweed (*Amaranthus* spp.) growth (Street *et al.*, 1981).

Higher cotton densities were more suppressive of sicklepod weed growth than were lower cotton densities (Webster, 2010).

Effect on weed dry weight (g/m^2) : The results revealed that different plant densities expressed their significant effect on weed dry weight (g/m^2) at 30 and 60 days after sowing (Table 1). Closer spaced crop (2,22,222 plants/ha) recorded significantly lower weed dry weight (31.8 g/m^2) as compared to 37.1 g/m^2 weed dry weight recorded in wider spaced crop (1,66,666 plants/ha) at 30 days after sowing. At 60 days after sowing, weed dry weight recorded in 1,66,666 plants/ha was 19.4 g/m^2, which was significantly higher than 16.7 g/m^2 recorded in 2,22,222 plants/ha treatment. Significantly lower numbers of weed plants/m^2 were recorded in treatment 2,22,222 plants/ha as compared to 1,66,666 plants/ha at 30 and 60 days after sowing. Due to shading effect of narrow sown cotton plants on weed flora in 2,22,222 plants/ha, the weed plants might not have fully developed. Hence, the weed dry weight might have recorded significantly lower than 1,66,666 plants/ha. Similar findings have also been recorded by other scientists. The average sicklepod biomass in ultra narrow spaced (25 cm) cotton significantly reduced by 80 per cent than conventional row spacing (91 cm) as reported by Street *et al.,* (1981). An inverse linear relationship between cotton plant population density and sicklepod plant biomass was also recorded by Webster (2010).

Effect on seed cotton yield:

Effect of plant density on yield : Closer spaced crop (2,22,222 plants/ha) recorded significantly higher seed cotton yield (2321 kg/ha) over 2112 kg/ha recorded in wider spaced crop (1,66,666 plants/ha). The results are supported by findings of Awan *et al.* (2011) and Venugopalan *et al.*, (2011). Different fertilizer levels could not influence the seed cotton yield per hectare. The influence of nitrogen and zinc might not have influenced significantly due to same level of these two nutrients in all the treatments. The non-significant responses of phosphorus and potash were earlier reported by Khistaria *et al.*, (1980). Interaction effect of plant densities and fertilizer levels (D x F) was found to be non-significant with respect to seed cotton yield (kg/ha). The average seed cotton yield produced in HDPS (2217 kg/ha) was significantly higher than control (1851 kg/ha). The results are supported with the findings of Venugopalan *et al.,* (2011) and Awan *et al.*, (2011) for seed cotton yield.

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Effect of conservation agriculture and residue management on yield and economics of cotton – Maize cropping system

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ABSTRACT : Field experiments were conducted at Cotton Research Station, Srivilliputtur during 2017 - 2018 and 2018-2019 to study the effect of conservation agriculture and residue management practices on yield and economics of cotton (September to January) – maize (February to June) cropping system under irrigated conditions. The experiments were carried out in a Randomized Block Design with three replications. The treatments consisted of control (T_{1} - Conventional tillage + No residue management), Zero tillage (ZT) + No residue management (T_2), ZT with 50 per cent residue management (T_3), ZT with 100 per cent residue management(T_4), Permanent Bed System (PBS) + ZT + No residue management (T_5), PBS + ZT + 50 per cent residue management (T_6), PBS + ZT + 100 per cent residue management (T_7).

The results revealed that though the conventional tillage without residue incorporation recorded the higher yields of cotton and maize in both the years of study, this was *on par* with that of zero tillage with 100 and 50 per cent residue management. Similar trend of comparable cotton equivalent yields were registered under ZT with 100 per cent residue management and ZT with 50 per cent residue management and PBS + ZT + 100 per cent residue management with the conventional tillage without residue incorporation. The labour requirement was minimised by 20 labourers / crop/ ha under ZT than conventional tillage. Adoption of ZT and PBS in the cotton – maize cropping system reduced the total cost cultivation by Rs. 12,000 / ha/ year and Rs.15,500 / ha/ year respectively. Though the higher gross income was associated with conventional tillage without residue application, higher net income and BC ratio were registered by zero tillage with residue application. Thus, it is concluded from the study that zero tillage under cotton- maize tillage was technically feasible which was comparable with conventional tillage without residue application on yield besides higher economic benefits and lesser labour use.

***Key Words** :* Conservation agriculture, cotton, economiccs, residue management, yield

Cotton also known as **"White Gold"** and **"King of Fibre Crops"** is an important fibre cum cash crop of India and Tamil Nadu as well. Maize, queen of cereals is the most versatile crop with wider adoptability in varied agro ecological conditions and there is an increasing trend is observed in the cultivation of maize in recent years. Among the total residues available in India, cereals including maize and cotton contribute 70 per cent (352 Mt) and 11 per cent

(53 Mt) respectively. (IARI, 2012). The crop residues which are having enormous value if utilized properly will have great potential for improving soil fertility, creation of pollution free environment besides improving yield of crops. Conservation agriculture is emerging as a big boost for crop production in India. It is based on minimal soil disturbance (Reduced or no / zero tillage), which may have great scope to save labour, time, fuel and machinery wear. The main concept of zero tillage is to avoid preparatory cultivation and without carrying any tillage operations. To manage the crop residues in a productive and profitable manner, conservation agriculture offer a good promise. Development of conservation agriculture based resource conserving technologies which are more resource efficient than conventional method of cultivation is paramount importance for long term sustainability. With this background, the present study was carried out.

MATERIALS AND METHODS

Field experiments were conducted at Cotton Research Station, Srivilliputtur during 2017 - 2018 and 2018-2019 to study the effect of conservation agriculture and residue management practices on yield and economics of cotton (September to January) – maize (February to June) cropping system under irrigated conditions. The experiments were carried out in a randomized block design with three replications. The treatments consisted of control (T_1 - Conventional tillage + No residue management), Zero tillage (ZT) + No residue management (T_2) , ZT with 50 per cent residue management (T_3), ZT with 100 per cent residue management(T_4), Permanent Bed System (PBS) + ZT + No residue management (T_5), PBS + ZT + 50 per cent residue management (T_6), PBS + ZT + 100 per cent residue management (T_7). The soil of the experimental field was clay loam with a pH of 8.26. The available nutrient N, P and K status of the soil was low (196 kg /ha), high (40 kg /ha) and high (446 kg /ha), respectively. The cotton variety SVPR 6 and hybrid maize (S 6668) were used for the study with a spacing of 75 x 30 and 75 x 20 cm, respectively. Ridges and furrow method of cultivation without residue application was followed in control treatment. Permanent bed system was prepared with a bed width of 125 cm and 25 cm furrow width. Cotton stalks were applied in between rows on the surface of maize field and *vice versa* by volume basis as per schedule. Observations on seed cotton yield and grain yield of maize were recorded and economics was also worked out.

RESULTS AND DISCUSSION

Yield of cotton and maize : The conventional tillage without residue incorporation recorded the highest kapas yield of cotton in both the years of study, but this was on par with that of zero tillage with 100 and 50 per cent residue management and significantly superior than other treatments except first year of cotton crop (Table 1). Similar trend of comparable yield under conventional tillage and zero tillage with both 100 and 50 per cent of residue application was also observed in maize. Being first crop of crop rotation, residues application and zero tillage were not practiced for cotton and hence non significant effect on

Table 1. Effect of conservation agriculture and residue management on yield of cotton- maize cropping system

Treatments	I year				II year			
	Seed cotton yield (kg/ha)	Grain yield of maize (kg/ha)	CEY of maize (kg/ha)	Total CEY of cropping system (kg/ha)	Seed cotton yield (kg/ha)	Grain yield of maize (kg/ha)	CEY of maize (kg/ha)	Total CEY of cropping system (kg/ha)
T_1	2028	5618	1556	3584	2069	4787	1977	4046
T_2	2017	5036	1395	3412	1873	4311	1781	3654
T_3	2019	5277	1462	3481	1966	4539	1875	3841
T_4	2022	5385	1492	3514	2012	4628	1912	3924
T_5	1986	4904	1358	3344	1804	4033	1666	3470
T_6	1995	5005	1386	3381	1837	4308	1779	3616
T_7	2001	5093	1411	3412	1925	4467	1845	3770
SEd.	74.2	180.2	-	-	71.1	141.2	-	-
CD(P=0.05)	NS	376.6	-	-	148.6	295.1	-	-

seed cotton yield was noticed during first year. Similar results from the field experiment at Akola minimum tillage recorded higher seed cotton yield than conventional tillage under rainfed conditions (Sonune *et al.*, 2013). Naveen Kumar and Babalad (2017) also found that both the conservation agricultural systems of no and reduced tillage with crop residue application registered significantly the higher yield of cotton than conventional tillage at UAS, Dharwad.

Cotton equivalent yield of cropping system : The conventional tillage without residue incorporation registered the highest cotton equivalent yield of 3584 and 4046 kg/ha during first and second year of study respectively (Table 1). This was followed by ZT with 100 per cent per cent residue management (3514 and 3924 kg/ha in I and II year) and ZT with 50 per cent residue management (3481 and 3841 kg/ha in I and II year) and PBS + ZT + 100 per cent residue management (3413 and 3770 kg/ha in

Table 2. Effect of conservation agriculture and residue management on economics and labour use of cotton- maize cropping System

Treat-ments	Economics 2017-18				Economics 2018-2019				Labour use (No /ha / year)	
	Cost of cultivation (Rs/ ha)	Gross Income (Rs/ ha)	Net Income (Rs/ ha)	BCR	Cost of cultivation (Rs/ ha)	Gross Income (Rs/ ha)	Net Income (Rs/ ha)	BCR	2017-2018	2018-2019
T_1	98200	163513	65313	1.67	110900	186127	75227	1.68	409	442
T_2	86200	155732	69532	1.81	98900	168067	69167	1.70	369	402
T_3	86200	158837	72637	1.84	98900	176677	77777	1.79	369	402
T_4	86200	160325	74125	1.86	98900	180484	81584	1.82	369	402
T_5	83200	152656	69456	1.83	95900	159611	63711	1.66	349	383
T_6	83200	154333	71133	1.85	95900	166354	70454	1.73	349	383
T_7	83200	155709	72509	1.87	95900	173423	77523	1.81	349	383

I and II year) in maize - cotton cropping system. The results of the field experiments at Pakhtunkhwa, Pakistan indicated that incorporation of maize stubbles prior to sowing of wheat lead to earlier emergence of seeds, taller plants, higher tiller production and higher grain yield of wheat (Abdul Basir *et al.,* 2015)

Number of labourers used in the cropping system : The number of labourers used for field operations were drastically reduced under conventional tillage than zero tillage and permanent bed system (Table 2). Totally 40 and 34 labourers / year/ ha was minimised under ZT and ZT + PBS respectively than conventional tillage.

Economics : The cost of cultivation was drastically reduced by the zero tillage and permanent bed system as compared to conventional tillage (Table 2). The saving in the total cost of cultivation in cotton was Rs. 6000 / ha and Rs.7000 / ha respectively under ZT and PBS as compared to conventional tillage and for maize, the similar reduction was Rs. 6000 / ha and Rs.7500 / ha respectively. Thus adoption of ZT and PBS in the cotton – maize cropping system reduced the total cost cultivation by Rs. 12,000 / ha and Rs.15,500 / ha respectively. Though the higher gross income was associated with conventional tillage without residue application, higher net income and BC ratio were registered by zero tillage with residue application.

Thus, it is concluded from the study that zero tillage under cotton- maize tillage was technically feasible and zero tillage with 100 per cent residue application registered comparable yield of cotton and maize with higher economic benefits and lesser labour use than conventional tillage without residue application.

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Quantitative relation of crop development and drying with temperature in different *Bt* cotton hybrids

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ABSTRACT : A field experiment was carried out at three different location *viz.,* Talod, Jagudan, Vijapur for three consecutive years (2010-2011, 2011-2012 and 2012-2013) to find the Quantitative relation of crop development and drying with temperature in different *Bt* cotton hybrids. The experiment was laid out in randomized block design with four replications and seven different *Bt* cotton hybrid *viz.,* Akka BGII, RCH – 138 BGII, Bijdhan-2 BGII, Gabbar BGII,Ninna BGII, Mallika-BGII and G.COT.HY -12. It was observed that night became cooler first at Jagudan than Vijapur and Talod, while reverse trend was observed for hot day *i.e.* Talod experienced first hot day, followed by Vijapur and Jagudan. As a result of such tress (increased respiration and reduced photosynthesis & cellular energy, temperature injury…), plant intend to close its vegetative as well as reproductive developments, which is clearly indicated by the reduction of node above top flower (NATF) from 5-6 to 1 or 2. The situation occurs frequently in north Gujarat as difficult to manage by any amendments. After cut-off, the intensive inputs are used for regeneration. This extends the crop duration by 90-100 days leading to reduced economic yield. Therefore farmers may advise to plant *rabi* crop if "cut-off" appears.

Key words : Cotton genotype, cut-off, forced maturity, over location, *Para wilt*, NATF, stress

Cotton (*Gossypium hirsutum* L.) the white gold, is one of the most important commercial and industrial crop. It plays a key role in economical and social affairs of the world. It is considered as **"King" of Fibers"** and being important cash crop of the country, benefits several million people who are engaged in its cultivation, trade, processing, manufacturing, etc. India ranks first in global cotton cultivation with an area of 12.84 m ha accounting 33 per cent of the world cotton area and stands second in production (386 lakh bales) next to China. However, the average productivity (511 kg lint/ ha) is low compared to the world average of 725 kg lint/ha (Anonymous, 2018).

In recent past, *Para wilt* is the major problems of cotton cultivation in north Gujarat. Many assumptions are made for the causes of *para wilt*, like high temperature, high ball load, poor soil fertility, *etc*.… but question is yet un-answered. The development rate of cotton is strongly influenced by temperature. A cotton crop grows more slowly on cool days than on warm days, so temperature measurements during the cropping season help estimate when a crop reaches a specific developmental stage. So it is urgent need to find out relation between heat received by cotton crop up to harvest and wilting. Waddle (1982) reported that when cotton produce opened flowers on the tops of the cotton plants is the first signal of cut-out or crop maturity. Therefore to investigate the relation between forced maturity of *Bt* cotton crop with temperature, "Nodes above top flower" (NATF) was taken as main character in this investigation.

MATERIALS AND METHODS

The present experiment was carried out at three different location *viz.,* Cotton Research Station, SDAU, Talod, Gujarat, Centre for Research on Seed Spices, SDAU, Jagudan, Gujarat, Centre of Excellence for Research on Wheat, SDAU, Vijapur, Gujarat for three consecutive years (2010-2011, 2011-2012 and 2012-2013) to find the quantitative relation of crop development and drying with temperature in different *Bt* cotton hybrids. The experiment was laid out in randomized block design with four replications and seven different *Bt* cotton hybrid *viz.,* Akka BGII, RCH – 138 BGII, Bijdhan– 2 BGII, Gabbar BGII,Ninna BGII, Mallika – BGII and G.COT.HY -12. To investigate the relation between forced maturity of *Bt* cotton crop with temperature, "Nodes above top flower" (NATF) was taken as main character in this investigation. For that, weekly observation on NATF and daily temperature (minimum and maximum) was recorded at Jagudan, Vijapur and Talod during 2010-2011, 2011-2012 and 2012-2013. Minimum and maximum temperatures were recorded by minimum and maximum thermometer. Average temperature of previous seven days was calculated and summarized on weekly base.

RESULTS AND DISCUSSION

Effect of temprature on NATP during 2010-2011 : From 16th August to 20th September, weekly average minimum, maximum and daily variation temperature in Jagudan was ranged from 22 to 25 ^{0}C, 32 to 35^{0}C and 7 to 12 ^{0}C, respectively. After 20th September, minimum weekly average temperature was fall below 22^{0}C, maximum weekly average temperature and daily variation weekly average temperature increased above 35 ^{0}C and 14 ^{0}C. Average NATF was reached below five on 27th September and 11th October. Average NATF recorded significant positive correlation with minimum temperature while, average NATF recorded significant negative correlation with maximum temperature as well as day-night temperature variation. The similar finding was observed by Loka *et al.,* (2010) that exposure to high temperature (>32°C) limits the growth and development of cotton. Due to high temperature regimes (27 and 30 °C) caused a significant increase in respiration rates by 49 per cent and 56 per cent, respectively, compared to those of the control (24 °C). ATP levels were significantly decreased proportionally to the increasing temperature regime.

From 16th august to 20th September, weekly average minimum, maximum and daily variation temperature in Vijapur was ranged from 22 to 27 ^{0}C, 32 to 35 ^{0}C and 3 to 8 ^{0}C, respectively. After 27th September, minimum weekly average temperature was reduced below 22 ^{0}C and maximum weekly average temperature increased above 35 ^{0}C. Weekly average temperature variation was crossed above 14 ^{0}C after 4th October. Average NATF was reached below five from 27th September to 11th October. Average NATF recorded significant positive correlation with minimum temperature while, negative significant correlation with maximum temperature as well as day-night temperature variation. In warm night leaf temperature remained high, with higher respiration, thereby consuming stored assimilates. Maintenance respiration approximately doubles over every 10 ^{0}C rise in temperature. Heat stress reduced the plant height, internodes, sympodial branches, monopodial branches, seeds per boll, boll weight, and fiber length during boll developmental process depending on temperature intensity and exposure period(Zafar *et al.,* 2017)

From 06th august to 22th October, weekly average minimum and maximum temperature in Talod was ranged from 22 to 30 ^{0}C**,** 31 to 36 ^{0}C and 3 to 8 ^{0}C**,** respectively. After that, maximum weekly average temperature increased above 35 ^{0}C. Weekly average daily variation temperature in Talod was below 14 ^{0}C during pick blooming period. The result observed that average NATF was reached below five from 15th October and then after. Average NATF was recorded significant positive correlation with minimum temperature as well as significant negative correlation with day and night temperature variation. Exposure to low average and cool night temperature (below 22°C) for extended period is also detrimental for cotton growth has been observed by Liu *et. al.,* (2015)

Effect of temprature on NATP during 2011-12 : During this year up to 5th October, weekly average minimum temperature in Jagudan was ranged from 22 to 25 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was ranged between 32 to 35 ^{0}C during pick blooming period. Weekly average temperature variation was crossed above 14 ^{0}C only after 5th October. Average NATF reached below five from 10th august and 28th September to 12th October as well as recorded significant negative correlation with day and night temperature variation only. It has been observed that mostly the heat stress is coupled with water deficit conditions, thus by causing sever injuries to plant cell membrane, disturbed protein synthesis and affecting the photosynthetic apparatus efficiency by reducing the transpiration due to stomata closure (Levitt, 1980).

From 09th August to 27th September, weekly average minimum temperature in Vijapur was ranged from 22 to 25 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was in ranged between 32 to 35 ^{0}C up to 11th October, afterward it increased above 35 ^{0}C and also weekly average temperature variation was crossed above 14 ^{0}C**.** Average NATF reached below five from 27th September to 25th October. Average NATF recorded significant positive correlation with minimum temperature while, negative significant correlation with maximum temperature as well as day-night temperature variation. Mohamed and Abdel-Hamid (2013) reported that imbalanced metabolism due to induced heat stress, plants' antioxidative defense system and biosynthesis of a number of new proteins referred to as heat shock proteins

Table 1. Number of Nodes above Top Flower and correlation with minimum, maximum and daily temperature variation during 2010-2011

LOCATION : JAGUDAN

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari- ation	Akka BG II	RCH- 138 BG II	Bijdhan- 2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
16-Aug	24.6	32.4	7.8	5.10	6.10	5.55	5.60	5.68	5.68	6.60	**5.76**
23-Aug	24.5	33.9	9.4	5.45	6.45	6.65	6.28	5.43	5.45	5.65	**5.91**
30-Aug	23.6	34.9	11.3	5.70	6.28	7.28	6.85	5.90	5.48	6.30	**6.25**
06-Sep	23.5	32.6	9.1	5.70	6.28	7.28	6.85	5.90	5.48	6.30	**6.25**
13-Sep	23.9	32.0	8.1	5.35	6.13	8.18	7.15	5.75	5.30	6.10	**6.28**
20-Sep	22.8	32.0	9.2	4.65	5.65	5.50	5.50	6.30	6.83	6.95	**5.91**
27-Sep	20.6	35.4	14.8	4.35	4.30	5.13	5.35	4.95	5.33	5.50	**4.99**
04-Oct	21.5	36.0	14.5	3.95	4.83	4.08	5.55	6.23	6.15	6.58	**5.34**
11-Oct	19.5	36.9	17.4	2.30	3.33	2.23	3.08	2.80	4.15	4.60	**3.21**
Correlation with Mini. temp.	0.88*	0.97*	0.81*	0.78*	0.66	0.39	0.59	0.86*			
Correlation with Max. temp.	-0.7*	-0.76*	-0.71*	-0.62	-0.61	-0.50	-0.64	-0.75*			
Correlation with daily variation of temp	-0.84*	-0.92*	-0.8*	-0.74*	-0.68*	-0.47	-0.65	-0.85*			

LOCATION : VIJAPUR

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari- ation	Akka BG II	RCH- 138 BG II	Bijdhan- 2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
16-Aug	25.9	31.1	5.2	5.05	6.10	6.00	5.75	5.50	5.65	6.40	**5.78**
23-Aug	26.3	30	3.7	5.25	6.45	7.30	6.48	5.35	5.35	6.13	**6.04**
30-Aug	24.9	31.6	6.7	5.45	6.58	7.43	6.78	6.05	5.90	6.90	**6.44**
06-Sep	25.7	30.3	4.6	5.70	6.40	7.90	6.75	6.20	5.65	6.58	**6.45**
13-Sep	24.6	29.6	5	5.05	5.80	5.55	6.08	6.10	6.90	7.35	**6.12**
20-Sep	23.6	31.3	7.7	4.45	4.45	5.20	5.35	5.15	5.50	6.60	**5.24**
27-Sep	21.4	31.9	10.5	2.43	4.73	4.10	5.28	5.05	6.13	6.80	**4.93**
04-Oct	22.9	35.6	12.7	2.40	3.10	1.95	3.00	2.20	4.00	4.60	**3.04**
11-Oct	20.8	35.5	14.7	0.70	1.90	1.50	1.75	1.90	1.70	3.05	**1.79**
Correlation with Mini. temp.	0.93*	0.86*	0.86*	0.79*	0.7*	0.57	0.57	0.81*			
Correlation with Max. temp.	-0.86*	-0.89*	-0.87*	-0.92*	-0.95*	-0.84*	-0.87*	-0.93*			
Correlation with daily variation of temp.	-0.96*	-0.94*	-0.93*	-0.92*	-0.9*	-0.77*	-0.79*	-0.94*			

contd...

Table 1 contd...

LOCATION : TALOD

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari-ation	Akka BG II	RCH-138 BG II	Bijdhan-2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
06-Aug	26.6	33.7	7.1	7.00	7.10	7.40	7.50	7.80	8.00	8.20	**7.57**
13-Aug	28.4	34	5.6	7.10	7.00	7.20	7.20	7.60	7.80	8.00	**7.41**
20-Aug	27.6	32.4	4.8	6.90	7.00	7.40	7.20	7.40	8.00	8.30	**7.46**
27-Aug	26.0	31.9	5.9	6.45	6.50	6.85	6.85	7.10	8.15	7.70	**7.09**
03-Sep	29.5	31.9	2.4	6.65	6.35	7.58	7.58	7.45	7.85	7.43	**7.27**
10-Sep	27.1	32.7	5.6	6.85	7.05	7.88	7.88	7.58	8.40	7.00	**7.52**
17-Sep	27.1	33.7	6.6	7.10	7.20	7.85	7.85	7.40	8.15	7.50	**7.58**
24-Sep	26.1	33.6	7.5	6.45	7.10	7.18	7.18	6.80	8.40	8.00	**7.30**
01-Oct	25.6	33.3	7.7	5.85	6.15	6.45	6.45	5.45	7.00	7.90	**6.46**
08-Oct	25	35.1	10.1	4.83	6.05	6.38	6.38	5.73	7.63	8.10	**6.44**
15-Oct	25.7	36	10.3	3.80	4.50	4.10	4.10	4.10	5.50	7.00	**4.73**
22-Oct	23.7	35.9	12.2	3.20	4.00	3.60	3.40	3.70	4.40	6.50	**4.11**
29-Oct	19.8	33.1	13.3	3.00	4.40	3.50	2.85	3.40	4.60	6.80	**4.08**
Correlation with Mini. temp.	0.82*	0.67*	0.79*	0.82*	0.81*	0.74*	0.39	0.78*			
Correlation with Max. temp.	-0.6	-0.59	-0.61	-0.56	-0.65*	-0.56	-0.27	-0.6			
Correlation with daily variation of temp	-0.9*	-0.77*	-0.88*	-0.88*	-0.9*	-0.81*	-0.39	-0.86*			

TABLE 2. Number of Nodes above Top Flower and correlation with minimum, maximum and daily temperature variation during 2011-2012

LOCATION : JAGUDAN

Date	Mini. temp. .(ºC)	Max. temp. (ºC)	Daily vari- ation	Akka BG II	RCH-138 BG II	Bijdhan-2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
10-Aug	24.8	33.1	8.3	3.88	5.93	4.18	3.78	5.13	5.60	5.20	**4.81**
17-Aug	22.5	28.8	6.3	5.53	6.10	5.65	5.33	5.85	5.65	4.53	**5.52**
24-Aug	24.7	33.0	8.3	5.88	6.65	6.48	5.35	5.95	5.80	5.38	**5.93**
31-Aug	23.1	33.1	10.0	5.88	6.65	6.48	5.35	5.95	5.80	5.38	**5.93**
07-Sep	22.9	33.2	10.3	5.70	6.10	6.98	6.30	6.35	6.73	6.53	**6.38**
17-Aug	23.1	32.6	9.5	5.60	5.80	7.90	6.58	6.58	6.60	6.55	**6.52**
21-Sep	23.0	31.2	8.2	5.10	5.93	6.73	5.53	5.98	6.20	6.00	**5.92**
28-Sep	23.5	32.5	9.0	4.23	4.38	5.83	4.03	3.93	4.33	4.50	**4.46**
05-Oct	23.2	33.5	10.3	3.35	3.13	4.30	3.55	3.90	4.03	4.00	**3.75**
12-Oct	20.2	34.4	14.2	1.73	1.80	2.30	1.73	1.28	1.23	1.00	**1.58**
Correlation with Mini. temp.	0.51	0.65*	0.43	0.41	0.6	0.64*	0.66*	0.58			
Correlation with Max. temp.	-0.47	-0.45	-0.35	-0.43	-0.46	-0.42	-0.28	-0.42			
Correlation with daily variation of temp	-0.66*	-0.73*	-0.63	-0.65*	-0.72*	-0.7*	-0.61	-0.7*			

LOCATION : VIJAPUR

Date	Mini. temp. .(ºC)	Max. temp. (ºC)	Daily vari- ation	Akka BG II	RCH-138 BG II	Bijdhan-2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
09-Aug	25.9	31.3	5.4	5.10	6.10	6.10	6.30	5.70	4.80	5.90	**5.71**
16-Aug	21.6	27.6	6	5.40	6.60	7.90	7.00	5.90	5.50	6.20	**6.33**
23-Aug	24.9	30.7	5.8	5.50	6.70	7.50	7.10	6.40	5.90	6.30	**6.47**
30-Aug	24.4	30.5	6.1	6.40	6.20	8.00	6.60	6.30	6.20	6.60	**6.61**
06-Sep	21.4	30.4	9	5.40	6.30	7.00	6.00	6.40	6.70	6.60	**6.34**
13-Sep	24.8	29	4.2	4.90	5.40	6.20	6.00	6.10	5.70	6.50	**5.81**
20-Sep	24.6	30.6	6	3.80	4.90	5.60	5.90	6.00	6.80	6.20	**5.59**
27-Sep	23	31.8	8.8	2.80	4.00	4.70	5.40	5.50	6.10	5.90	**4.89**
04-Oct	21.1	32.4	11.3	2.50	3.60	4.20	4.60	4.70	5.40	5.50	**4.33**
11-Oct	21.7	35	13.3	1.60	3.30	3.60	4.10	3.90	4.60	5.30	**3.75**
18-Oct	21.9	36.1	14.2	1.30	2.90	3.10	2.70	2.80	3.50	3.60	**2.82**
25-Oct	19.8	35	15.2	1.00	1.90	2.40	1.90	2.10	2.50	2.50	**2.04**
Correlation with Mini. temp.	0.62	0.72*	0.73*	0.8*	0.75*	0.65*	0.71*	0.75*			
Correlation with Max. temp.	-0.86*	-0.85*	-0.85*	-0.89*	-0.93*	-0.85*	-0.86*	-0.91*			
Correlation with . daily variation of temp	-0.88*	-0.84*	-0.85*	-0.92*	-0.91*	-0.83*	-0.86*	-0.9*			

contd...

Table 2 *contd...*

LOCATION : TALOD

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari- ation	Akka BG II	RCH- 138 BG II	Bijdhan- 2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
20-Aug	23.9	31.8	7.9	7.05	6.90	7.45	7.55	7.80	8.30	8.20	**7.61**
27-Aug	22.8	33.7	10.9	6.65	6.80	7.60	7.45	7.20	7.55	7.90	**7.31**
03-Sep	24.4	32.4	8.0	6.85	6.85	7.90	7.18	6.05	7.25	7.63	**7.10**
10-Sep	24.5	31.5	7.0	6.05	6.98	8.03	7.48	6.75	7.80	7.40	**7.21**
17-Sep	22.7	31.6	8.9	6.30	6.80	8.50	7.45	6.90	7.55	7.08	**7.23**
24-Sep	20.8	33.0	12.2	5.65	6.20	6.15	6.78	6.80	7.80	7.85	**6.75**
01-Oct	20.1	34.7	14.6	5.05	4.85	5.80	6.05	5.85	6.40	7.10	**5.87**
08-Oct	21.5	36.5	15.0	3.03	5.13	4.70	5.98	5.75	6.03	6.30	**5.27**
15-Oct	17.2	35.7	18.5	3.00	3.50	2.55	3.70	2.90	4.90	5.10	**3.66**
22-Oct	17.7	35.1	17.4	1.30	2.30	2.10	2.45	2.60	2.60	3.55	**2.41**
Correlation with Mini. temp.	0.84*	0.93*	0.92*	0.91*	0.85*	0.83*	0.81*	0.9*			
Correlation with Max. temp.	-0.82*	-0.78*	-0.83*	-0.71*	-0.68*	-0.71*	-0.65*	-0.77*			
Correlation with daily variation of temp	-0.89*	-0.92*	-0.95*	-0.87*	-0.81*	-0.81*	-0.76*	-0.89*			

TABLE 3. Number of Nodes above Top Flower and correlation with minimum, maximum and daily temperature variation during 2012-2013

LOCATION : JAGUDAN

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari-ation	Akka BG II	RCH-138 BG II	Bijdhan-2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
06-Aug	24.5	33.5	9.0	3.50	3.60	3.90	3.30	3.15	3.15	3.30	**3.41**
13-Aug	23.1	33.1	10.0	4.70	3.70	4.55	3.35	3.90	3.70	3.73	**3.95**
20-Aug	23.3	33.1	9.8	3.55	3.55	3.80	3.50	4.15	3.50	3.35	**3.63**
27-Aug	24.0	33.1	9.1	3.35	3.25	3.20	3.45	3.25	3.35	3.20	**3.29**
03-Sep	24.1	34.0	9.9	3.25	3.10	3.20	3.55	3.30	3.30	3.30	**3.29**
10-Sep	23.2	31.9	8.7	3.40	3.50	3.45	3.30	3.25	3.15	3.30	**3.34**
17-Sep	23.0	30.5	7.5	3.30	3.40	3.60	3.25	3.50	3.60	3.30	**3.42**
24-Sep	22.8	34.0	11.2	3.25	3.30	3.55	3.40	3.45	3.45	3.50	**3.41**
01-Oct	21.6	34.7	13.1	2.18	1.78	2.20	3.23	2.75	2.80	2.30	**2.46**
08-Oct	22.3	36.3	14.0	1.30	1.05	1.45	1.45	1.85	1.45	1.45	**1.43**
15-Oct	21.2	35.8	14.6	1.55	1.70	1.50	1.40	1.75	2.15	1.95	**1.71**
Correlation with Mini. temp.	0.67*	0.73*	0.68*	0.69*	0.68*	0.63	0.71*	0.71*			
Correlation with Max. temp.	-0.71*	-0.82*	-0.76*	-0.7*	-0.73*	-0.79*	-0.76*	-0.78*			
Correlation with daily variation of temp	-0.8*	-0.9*	-0.89*	-0.78*	-0.82*	-0.83*	-0.86*	-0.88*			

LOCATION : VIJAPUR

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari-ation	Akka BG II	RCH-138 BG II	Bijdhan-2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
23-Aug	25.4	30.9	5.5	3.50	5.50	6.40	6.20	5.70	4.70	4.90	**5.30**
30-Aug	25.6	30.4	4.8	4.40	6.30	7.00	6.30	5.90	5.50	5.60	**5.80**
06-Sep	25.4	31.2	5.8	5.20	6.60	7.80	7.40	6.40	6.00	6.20	**6.50**
13-Sep	25.4	29.1	3.7	6.00	7.10	8.30	7.80	6.30	6.40	6.60	**6.90**
20-Sep	25.1	31.6	6.5	6.00	7.10	8.30	7.80	6.30	6.40	6.60	**6.90**
27-Sep	24.7	32.6	7.9	6.20	7.50	8.60	7.90	6.40	6.80	6.90	**7.20**
04-Oct	24.9	36.1	11.2	7.00	7.30	9.00	8.30	6.10	7.40	7.10	**7.40**
11-Oct	23	36.4	13.4	5.90	6.40	7.10	7.40	6.90	6.70	6.10	**6.60**
18-Oct	20.1	35.6	15.5	5.00	5.10	6.00	6.10	6.00	6.00	5.40	**5.60**
25-Oct	20.3	35.5	15.2	3.50	3.90	4.80	4.80	4.60	5.30	5.00	**4.60**
01-Nov	18.8	35.3	16.5	2.10	2.20	2.40	2.70	2.40	3.00	3.00	**2.50**
08-Nov	18.6	35.2	16.6	1.00	1.60	1.50	1.60	1.40	1.90	2.10	**1.60**
Correlation with Mini. temp.	0.71*	0.94*	0.94*	0.91*	0.81*	0.81*	0.9*	0.9*			
Correlation with Max. temp.	-0.19	-0.47	-0.46	-0.42	-0.34	-0.25	-0.4	-0.4			
Correlation with . daily variation of temp	-0.5	-0.8*	-0.79*	-0.75*	-0.64*	-0.62	-0.74*	-0.74*			

contd..

Table 3 *contd...*

LOCATION : TALOD

Date	Mini. temp. .(°C)	Max. temp. (°C)	Daily vari- ation	Akka BG II	RCH- 138 BG II	Bijdhan- 2 BG II	GABBAR BG II	NINNA BG II	MALLIKA BG II	G.COT. HY -12	**Average**
20-Aug	26.0	28.0	2.0	5.35	6.30	6.50	6.05	5.70	7.35	7.20	**6.35**
27-Aug	26.0	29.0	3.0	5.55	6.65	6.80	6.78	5.55	7.05	6.93	**6.47**
03-Sep	24.0	27.0	3.0	5.75	6.78	6.93	7.08	6.25	7.60	6.70	**6.73**
10-Sep	24.0	27.0	3.0	6.00	6.60	7.40	7.05	6.40	7.35	6.38	**6.74**
17-Sep	25.0	32.0	7.0	5.35	6.00	6.05	6.38	6.30	7.60	6.15	**6.26**
24-Sep	25.0	35.0	10.0	4.75	4.65	5.70	5.65	5.35	6.20	6.40	**5.53**
01-Oct	24.5	37.6	13.1	3.73	4.93	4.60	5.58	5.25	6.83	6.60	**5.36**
08-Oct	23.0	38.0	15.0	2.70	3.30	3.20	3.30	3.70	4.70	4.40	**3.61**
15-Oct	21.0	37.6	16.6	2.50	2.10	2.50	2.05	2.70	3.20	4.00	**2.72**
22-Oct	18.0	35.0	17.0	2.00	1.50	2.20	1.80	1.20	2.70	3.00	**2.06**
	20.0	36.4	16.4	1.80	1.10	1.50	1.20	1.00	2.10	2.20	**1.56**
Correlation with Mini. temp.	0.26	0.88*	0.84*	0.88*	0.91*	0.90*	0.92*	0.89*			
Correlation with Max. temp.	-0.53	-0.78*	-0.82*	-0.75*	-0.64*	-0.66*	-0.58	-0.74*			
Correlation with . daily variation of temp	-0.96*	-0.94*	-0.96*	-0.92*	-0.88*	-0.87*	-0.79*	-0.92*			

Note : All the temperatures (mini. and max.) are the average of temperature of previous seven days while daily vareation is the average of the diffrence of the daily maximum and minimum temperature of previous seven days of corresponding date

(HSPs) get activated to protect plant from oxidative and membrane damage at sub optimal temperatures.

During this year up to 17th September, weekly average minimum temperature was in the ranged from 22 to 25 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was in ranged between 32 to 35 ^{0}C upto 1st October, afterward maximum weekly average temperature increased above 35 ^{0}C. Weekly average temperature variation was crossed above 14^{0}C also after 1st October and remarkably reached up to 18.5 ^{0}C on 15th October. Average NATF reached to below five on 1st to 22th October. Average NATF recorded significant positive correlation with minimum temperature while, negative significant correlation with maximum temperature as well as day-night temperature variation. High temperature caused a significant increase in whole-plant water loss (regardless of CO2 levels) thus reducing whole-plant water use efficiency (Broughton *et al.,* 2017)

Effect of temprature on NATP during 2012-2013 : From 06th august to 24th September, weekly average minimum temperature in Jagudan was ranged from 22 to 25 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was ranged between 32 to 35 ^{0}C up to 1st October, afterward; maximum weekly average temperature was increase above 35 ^{0}C. Weekly average temperature variation was crossed above 14 ^{0}C from 1st October. average NATF reached below five from 06th August and 15th October as well as recorded significant positive correlation with minimum temperature while, negative significant correlation with maximum temperature as well as day-night temperature variation. Ashley (1972) observed that carbohydrate assimilation during boll development in cotton plant is primarily (> 60 per cent) comes from the subtending leaf of boll due to high temperature.

During this year up to 11th October, weekly average minimum temperature Vijapur was ranged of 22 to 26 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was in ranged between 32 to 35 ^{0}C upto 27th September, afterward maximum weekly average temperature was surged above 35 ^{0}C. Weekly average temperature variation was crossed above 14 ^{0}C from 11th October. Average NATF reached below five from 25th October to 08th November as well as recorded significant positive correlation with minimum temperature and day and night temperature variation.. leaf also influenced badly during the hot spells of temperature and drought stress, thus affecting the photosynthetic rate which ultimately imbalances the carbohydrate production in leaf (Snider *et al.,* 2009)

Up to 8th October, weekly average minimum temperature in Talod was ranged from 22 to 26 ^{0}C and it falls below 22 ^{0}C afterward. Weekly maximum average temperature was in ranged between 32 to 35 ^{0}C up to 17th September, afterward maximum weekly average temperature was surged above 35 ^{0}C. Weekly average temperature variation was crossed above 14 ^{0}C after 1st October. During the year, average NATF reached below five from 8th October to 29th October while, recorded significant positive correlation with minimum temperature and negative significant correlation with maximum temperature as well as day-night temperature variation. When temperature is higher (more than 35R” centigrade), plant use transpiration to regulate temperature of their canopy. When increased transpiration and soil evaporation so, lowering water use efficiency.This complex situation culminated in plant trees associate with higher evaporative demand regardless of water availability in the soil. (Michel, 2007). Abrol and Ingram (1996) also reported that in semi-arid regions and other agro-ecological zones where there is wide variation in diurnal temperature could markedly increase the frequency of injury attributed by high temperature.

Major findings about minimum, maximum and daily temperature variation : Night became cooler at Jagudan was started after 20th September, 5th October, 24th September ; at Vijapur 20th September, 27th September, 11th October and at Talod 22th October, 17th September, 11th October during 2010-2011, 2011-2012 and 2012-2013, respectively.

At Jagudan, day became hotter reported after 20th September, 12th October and 1st October during 2010-2011, 2011-2012 and 2012-2013 respectively. At Vijapur, day became hotter observed after 27th September during 2010-2011 and 2012-2013, while from 4th October, in 2011-2012 and at Talod day became hotter found after 1st October during 2010-2011 and 2011-2012, whereas from 17th September in 2012-2013.

Drastic change in day and night temperature at Jagudan was reported after 20th September, 5th October, 1st October and at Talod was observed after 29th October, 24th September and 1st October during 2010-2011, 2011-2012 and 2012-2013, respectively. At Vijapur, change in day and night temperature was observed after 4th October in 2010-2011, whereas it was observed after 4th October during 2011-2012 and 2012-2013. Drastic change in day and night temperature (more than 14R” centigrade) was started during 1st fortnight of October.

CONCLUSION

From the above study it was further concluded that night became cooler first at Jagudan than Vijapur and Talod, while reverse trend was observed for hot day *i.e.* Talod experienced first hot day, followed by Vijapur and Jagudan. Nodes above top flower reduced below five when maximum temperature reached 35 ^{0}C and above with higher night temperature for one to two weeks and immediate followed by cooler night. As a result of such tress (increased respiration, reduced photosynthesis, cellular energy and temperature injury...), plant intend to close its vegetative as well as reproductive developments, which is clearly indicated by the reduction of NATF from 5-6 to 1 or 2.

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Evaluation of cotton genotypes for seed oil, protein, gossypol contents

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ABSTRACT : The seeds of 34 genotypes were analyzed for oil, gossypol and protein content. Experiment was conducted at Main Cotton Research Station, Navsari Agriculture University, Surat during 2017-2018. The results showed significant variations amongst the genotypes. Significantly higher oil content was observed in cotton genotypes ARBH 1701 (18.12%) followed by PBH 116 (18.04%) and RAH 0603 (18.00%). Gossypol content ranges from 37.47 to 156.49 (mg/100g of tissue) in different entries. Lowest gossypol content was observed in CPD 1701 (37.47 mg/100g of tissue) followed by F 2662 & GISV 319 (39.3726 mg/100g of tissue) and PBH 139 (44.47 mg/100g of tissue). Higher gossypol content was found in PBH 116 and RB 607 (156.49 and 153.26 mg/100g of tissue) respectively. Highest protein content was observed in SHJ 23 (23.72 mg/g of tissue) which was followed by HS 300 and F 2596 (23.08 and 21.94 mg/g of tissue) respectively.

Cottonseed oil (*Gossypium hirsutum* L.) has long been considered to be a good vegetable oil for frying, in part because it tends to impart a toasted aroma to fried products. Cottonseed oil also has disadvantages that have resulted in some food companies limiting their use of the oil. Specifically, the oxidative stability of cottonseed oil can be lower than other vegetable oils because of its high concentration of linoleic acid (18:2). When used for frying, this instability accelerates the formation of off-flavors (rancidity) and shortens oil life. Although the level of these acids is significantly reduced by oil deodorization, they would be fully present in whole seed or kernel feeding of cottonseed to animals, a practice that would increase if current efforts to reduce seed gossypol levels prove successful [1]. Protein content and Fatty acid profile of cottonseed oil were varies from genotypes to genotypes. However, considerable background information is needed to study the degree of compositional variation that exists in the seed oil, gossypol and protein content of cotton genotypes. In viewing this experiment was conducted.

MATERIALS AND METHODS

The seeds of 34 genotypes were analyzed for oil, gossypol and protein content. Experiment was conducted at Main Cotton Research Station, Navsari Agriculture University, Surat during 2017-18.

1. **Oil analysis:** Cotton seed of 38 genotypes were collected from Indo American section of Main Cotton Research Station, NAU, Surat. Seeds of 34 cotton genotypes were crushed to make a powder for Oil analysis by Near Infra Red spectroscopy (Table 1).

2. **Protein analysis:** Protein was estimated from cotton seed by standard methods of Lowry [2].

3. **Gossypol estimation:** Gossypol content was estimated from cotton seed by standard methods [3].

Table 1. List of entry used for evaluation

Entry code	Name of entry
701	RS 2906
702	BS 2-17
703	GJHV-520
704	ARBH 1701
705	RAH 0603
706	BGDS 0607
707	GSHV 199
708	PBH 139
709	F 2662
710	CPD 1702
711	RB 607
712	ZC
713	RS 2913
714	GISV 319
715	CSH 3419
716	F 2596
717	HS 300
718	LC
719	SHJ 23
720	RB 608
721	GJHV-523
722	TSH 325
723	H 1488
724	CPD 1701
725	RAH 0604
726	PBH 116
727	QC (Suraj
728	TCH 1828
729	TVH 001
730	RHC 1346
731	H 1508
732	BS 3-17
733	CSH 1604
734	TSH 332

RESUTLS AND DISCUSSION

The seeds of thirty four genotypes were analyzed for oil, gossypol and protein content.

Table 2. Evaluation of cotton genotypes for seed oil, gossypol and protein

Genotypes (Entry code)	Oil content (%)	Protein content(mg/ g of tissue)	Total Gossypol(mg/ 100g of tissue)
701	17.50	17.18	72.36
702	16.53	15.35	64.51
703	17.87	15.10	118.13
704	18.12	17.30	95.10
705	18.00	14.61	64.51
706	17.56	15.55	64.37
707	17.85	21.41	68.05
708	17.32	20.51	44.47
709	17.45	17.47	39.37
710	17.29	15.48	45.99
711	17.31	18.14	153.26
712	16.80	21.61	71.09
713	17.14	16.14	151.26
714	17.50	12.39	39.37
715	17.51	12.67	44.86
716	17.34	21.94	58.36
717	17.26	23.08	45.35
718	17.24	21.78	48.51
719	17.02	23.72	61.04
720	17.22	19.63	57.86
721	16.82	13.57	61.73
722	17.25	16.54	125.26
723	17.23	13.70	46.89
724	17.66	17.52	37.47
725	16.72	16.28	113.71
726	18.04	16.83	156.49
727	17.21	16.42	49.32
728	17.28	15.24	57.93
729	17.22	18.29	61.76
730	16.76	18.12	126.84
731	17.41	13.68	131.40
732	17.33	20.46	115.66
733	17.12	14.07	134.05
734	17.38	12.13	139.26
SE.d	0.043	0.273	1.65
CD (p=0.05)	0.086	0.546	3.30

The results (Table 2) showed significant variations amongst the genotypes. Significantly higher oil content was observed in PBH 21(17.18%) followed by CCH 15-2(17.07%), SHM-55(17.01%), RAH 1069(17.01%). Gossypol content ranges from 36.46 to 171.70 mg % in different entries. Lowest gossypol content was observed in RAH 1069(36.46 mg %) followed by ARBH-1501(39.81 mg %), TSH 321(44.71 mg %) and CNH 147-1(45.76 mg %). Free gossypol content across *Bt* varieties ranged from 115-414 mg per cent while it reported to be ranging from 199-414 mg [4]. Processing of cottonseed was reduced the gossypol content. Highest protein content was observed in CNH 126(25.34%) which was followed by RB-602(22.85%) and Local Check (G.Cot-20) (22.7%). Our results of Cotton seed oil, Protein and gossypol were revealed the similarity with the early year report [5].

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Effect of different sources of nutrients on organic cotton production under rainfed upland ecosystem of Odisha

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ABSTRACT : A field experiment was conducted at the research farm of All India Coordinated Research Project on Cotton located in Regional Research and Technology Transfer Station, Bhawanipatna under Odisha University of Agriculture and Technology during *kharif* 2016-2017, 2017-2018 and 2018-2019. The trial was laid out in randomized block design with three replications and eleven treatments. Results of the experiment revealed that the treatment RD of nutrient through inorganic source recorded significantly the maximum seed cotton yield (1657 kg /ha) which was *at par* with that obtained from RD of nutrient through organic sources based on P equivalent basis with 1615 kg /ha. Absolute control (No organic and inorganic) recorded the lowest seed cotton yield (965 kg /ha). The treatment RD of nutrient through inorganic recorded the maximum gross return/ha (Rs 90,292), net return (Rs 53,259) and B:C ratio (2.44) followed by the treatment RD of nutrient through organic sources based on P equivalent basis with gross return/ha (Rs. 88,038), net return (Rs. 50,471) and B:C ratio (2.34). The lowest gross return (Rs. 52,574), net return (Rs. 18,408) and B:C ratio (1.54) was recorded in absolute control.

Key words: Bio fertilizer, green manure, organic cotton, vermicompost

Productivity of cotton in India is far below as compared to global standards. The modern cotton production technology relies heavily on the use of fertilizers and chemicals to control insect pests, diseases and weeds. Cotton cultivated on 5 per cent cultivable land consumes 54 per cent of total pesticides used in Indian agriculture. Use of chemicals at such scale leads to immense ecological and human hazards as reported by the World Health Organization. So, to protect the environment and maintain the cotton productivity at a sustainable level, organic sources of inputs is inevitable. Organic farming creates rural employments and uses on-farm resources to make it more cost-effective. Several workers reported beneficial use of farm yard manure (Blaise *et al.*, 2005), vermicompost (Saranraj and Stella, 2012), castor cake (Silva *et al.*, 2013), green manuring (Blaise, 2011) and biofertilizer like Azotobacter and phosphorus solubilizing bacteria (Narula *et al.*, 2011) for increasing cotton productivity. Thus, keeping this in view, the present investigation was undertaken to study the effect of different organic sources of nutrients in sustaining the cotton productivity in Western Undulating Zone of Odisha under rainfed ecosystem.

MATERIALS AND METHODS

The field experiment was carried out at the research farm of All India Coordinated Research Project on Cotton located in the Regional Research and Technology Transfer Station, Bhawanipatna under the Odisha University of Agriculture and Technology during *kharif* 2016-2017, 2017-2018 and 2018-2019. The soil of the experimental site was clay loam, low in available N, medium in available P and K with pH of 6.1. The trial was laid out in randomized block design with three replications and eleven treatment *viz.,* T_1: Absolute control (No organic and inorganic), T_2: Control (RDF through inorganic), T_3: RD of Nutrient through organic based on P equivalent basis (12.5 t /haFYM), T_4: Seed treatment and soil application of biofertilizers (Azotobacter and PSB) and foliar application of PPFM @1 per cent at flowering and boll development stage, T_5: *Neem* cake 250 kg /ha , T_6: Raising of sunhemp between rows and incorporated before flowering (12 t /ha), T_7: Intercropping with soybean and crop residue application after pod plucking (1.5 t /ha), T_8:T_4 + *Neem* cake 250 kg /ha, T_9 : T_4 + Raising of sunhemp between rows incorporated before flowering (12 t /ha), T_{10}: T_4 + Neem cake 250 kg /ha + green manuring with Sunhemp and T_{11}: T_4 + Neem cake 250 kg /ha + green manuring with Soybean. The recommended dose (RD) of fertilizer for cotton in Odisha is 90:45:45 kg /ha. The cotton variety Suraj was sown during the first week of July each year with a spacing of 90 x 60 cm. The crop was raised organically with different sources of nutrients as per the treatments.

. Seed was treated with biofertilizer like Azotobacter and phosphorus solubilizing bacteria (PSB) @ 25 g/kg of seed each on the date of sowing. All the inputs were applied as basal dose only. Sunhemp was sown in the inter row spaces one day after sowing (DAS) of cotton seeds and incorporated into the soil at 30 DAS. Soybean was grown as intercrop between two rows of cotton and incorporated as green manure before pod formation stage. The crop was harvested in three plucks after four months of sowing at 15 days intervals in boll bursting stage. The rainfall received during the cropping seasons of 2016-2017 and 2017-2018 and 2018-2019 was 1248 mm, 1303 mm and 1709 mm, respectively.

RESULTS AND DISCUSSIONS

Results of the experiment (pooled data over three years) revealed that different growth and yield parameters and seed cotton yield were significantly affected by different treatments. The treatment RD of nutrient through inorganic source (T_2) recorded significantly the maximum seed cotton yield (1657 kg /ha) which was a*t par* with that obtained from RD of nutrient through organic sources based on P equivalent basis (T_3) with 1615 kg /ha. Absolute control (No organic and inorganic) recorded the lowest seed cotton yield (965 kg /ha). Similar results were obtained by Silva (2013) and Saranraj *et al.,* (2012).

T_2 recorded significantly the highest plant height (103.67 cm), minimum monopodia (1.71), maximum sympodia (15.38), maximum number of bolls/m^{-2} (41.51) and boll weight (4.1 g). T_3 was statistically a*t par* with T_2 with respect to all the parameters like plant height (99.73 cm), monopodia (1.75), sympodia (13.84), bolls/m^2 (35.03) and boll weight (4.0 g). The absolute

Table 1. Growth characters, Seed cotton yield (kg/ha) and organic carbon (per cent) as influenced by organic methods of cultivation (Pooled data for three years)

Treatments	Plant height (cm) at harvest	Monopodia at harvest	Sympodia at harvest	Bolls/ SQM	Boll weight (g)	Seed cotton yield (kg/ha)	Organic carbon (per cent) initial	final
T1. Absolute control (No organic& inorganic)	64.73	1.93	10.01	24.47	2.6	965	0.49	0.50
T2. Control (RDN through inorganic)	103.67	1.71	15.38	41.51	4.1	1657	0.60	0.65
T3.RD of Nutrient through organic based on P equivalent basis	99.73	1.75	13.84	35.03	4.0	1615	0.60	0.64
T4. Seed treatment and soil application of recommended bio fertilisers and foliar application of PPFM	67.67	1.97	11.11	26.46	3.0	1107	0.51	0.56
T5. Neem cake 250 kg/ha	75.40	1.90	11.84	28.07	3.2	1210	0.53	0.60
T6. Raising of Sun hemp/ fodder cowpea between rows incorporated before flowering	71.53	1.91	10.98	27.39	3.1	1158	0.51	0.57
T7. Intercropping with green gram/black gram/ ground nut/soybean	70.00	1.89	11.04	26.25	2.7	1051	0.52	0.57
T8.T4+T5	80.93	1.84	13.38	31.09	3.7	1444	0.52	0.56
T9.T4+T6	78.60	1.89	11.78	30.10	3.5	1397	0.58	0.60
T10.T4+T5+T6	82.73	1.83	13.31	31.21	3.8	1475	0.54	0.60
T11.T4+ T5 + T7	77.40	1.89	11.44	29.11	3.4	1382	0.53	0.57
SEd	1.53	0.03	0.37	0.55	0.10	51.17	0.02	0.02
CD (p=0.05)	4.51	0.08	1.10	1.61	0.29	150.93	0.05	0.05

control recorded the minimum growth and yield parameters among all the treatments.

The uptake of N, P and K was significantly affected by different treatments depending upon their initial availability in the soil, amount of nutrients applied and the growth of the plants. The uptake was significantly the highest in T_2 (78.8, 25.8 and 76.4 kg/ha N, P and K, respectively) followed by T_3 (75.6, 24.8 and 71.9 kg/ha N, P and K, respectively). The uptake was the minimum in absolute control T_1 (46.6, 10.8 and 39.5 kg/ha N, P and K, respectively).The availability of these nutrients slightly increased at harvest than that in the initial stages (before sowing) in all the treatments.

The treatment RD of nutrient through inorganic (T_2) recorded the maximum gross return/ha (Rs 90,292), net return (Rs 53,259) and B:C ratio (2.44) followed by the treatment RD of nutrient through organic sources based on P equivalent basis (T_3) with gross return/ha (Rs. 88,038), net return (Rs. 50,471) and B:C ratio (2.34). The lowest gross return (Rs. 52,574), net return (Rs. 18,408) and B:C ratio (1.54) was recorded in absolute control.

CONCLUSION

Application of recommended dose of nutrient through organic sources based on P equivalent basis (FYM 5t /ha + castor cake 500 kg /ha + vermicompost 5t /ha) + green

Table 2. Nutrient uptake (kg/ha), nutrient availability (kg/ha) and economics as influenced organic methods of cultivation (Pooled data for three years)

Treatment	Nutrient uptake (kg/ha)			Nutrient availability (kg/ha)					
				Initial			Final		
	N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T1. Absolute control (No organic& inorganic)	46.6	10.8	39.5	120.5	34.1				
T2. Control (RDN through inorganic)	78.8	25.8	76.4	126.1	38.5	245.9	128.9	40.5	248.6
T3.RD of Nutrient through organic based on P equivalent basis	75.6	24.8	71.9	121.1	38.1	242.5	126.2	40.1	247.7
T4. Seed treatment and soil application of recommended bio fertilisers and foliar application of PPFM	53.3	12.9	44.9	119.1	31.6	235.3	124.9	33.6	234.9
T5. Neem cake 250 kg/ha	57.1	18.9	52.5	121.8	35.6	226.9	126.2	37.6	229.6
T6. Raising of Sun hemp / fodder cowpea between rows incorporated before flowering	55.6	16.6	55.4	115.1	33.5	236.2	120.9	35.2	239.0
T7. Intercropping with green gram/black gram/ ground nut/soybean	55.0	14.9	46.5	120.1	31.7	241.9	124.5	33.7	244.6
T8.T_4+T_5	75.9	22.4	65.9	125.5	32.3	237.1	129.9	34.3	239.3
T9.T_4+T_6	67.5	21.8	62.2	122.1	34.6	237.4	127.9	36.6	235.3
T10.T_4+T_5+T_6	73.4	23.3	63.2	125.8	33.6	245.7	131.2	35.6	244.6
T11.T_4+ T_5 + T_7	69.1	21.8	56.3	121.5	34.8	230.2	126.5	36.8	232.9
SEd	2.09	1.78	1.73	2.34	0.85	2.25	2.29	0.90	2.46
CD (p=0.05)	6.16	5.38	5.11	6.90	2.49	6.63	6.76	2.65	7.27

Table. 2. Nutrient uptake (kg/ha), nutrient availability (kg/ha) and economics as influenced organic methods of cultivation (Cont.)

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net Return (Rs/ha)	B:C ratio
T1. Absolute control (No organic& inorganic)	34167	52574	18408	1.54
T2. Control (RDN through inorganic)	37033	90292	53259	2.44
T3.RD of Nutrient through organic based on P equivalent basis	37567	88038	50471	2.34
T4. Seed treatment and soil application of recommended bio fertilisers and foliar application of PPFM	35000	60334	25334	1.72
T5. Neem cake 250 kg/ha	35667	65941	30274	1.85
T6. Raising of Sun hemp / fodder cowpea between rows incorporated before flowering	36400	63095	26695	1.73
T7. Intercropping with green gram/black gram/ ground nut/soybean	35267	57275	22009	1.62
T8.T_4+T_5	36300	78684	42384	2.17
T9.T_4+T_6	37000	76135	39135	2.06
T10.T_4+T_5+T_6	38200	80414	42214	2.11
T11.T_4+ T_5 + T_7	35833	75309	39475	2.10
SEd	358.69	2788.77	2755.83	0.08
CD (p=0.05)	1057.97	8225.63	8128.47	0.23

manuring with sunhemp @ 50kg /ha recorded significantly the highest seed cotton yield (1615 kg /ha) being a*t par* with application of RD through inorganic sources (1657 kg /ha) along with improvement in yield attributes and economics.

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Influence of tillage and weed management practices on cotton green gram cropping system

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ABSTRACT : A field experiment was conducted during *kharif-rabi* season of 2016-2017 at AICRP-Weed Management, Anand Agricultural University, Anand (Gujarat) to study the influence of tillage and weed management practices on cotton-green gram cropping system. Results indicated that in cotton total weed density and dry biomass at harvest was recorded the highest under zero tillage + zero tillage and zero tillage + zero tillage + residue incorporation treatments, respectively. Significantly the highest seed cotton yield was obtained under conventional tillage treatment (2.52 t/ha) and pendimethalin 900 g/ha PE *fb* IC+HW at 30 and 60 DAS (2.33 t/ha). While in greengram, significantly the lowest weed density and weed dry biomass (7.19 no./m^2 and 6.90 no./m^2) was recorded at 30 DAS in conventional tillage followed by conventional tillage (CT-CT) treatment, respectively. The highest yield of green gram was recorded under zero tillage + residue followed by zero tillage + residue (ZT+R-ZT+R) treatment and pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS. The variable results were observed with respect to various tillage practices in suppression of density and dry weight of weeds in cotton greengram cropping system. Different tillage practices showed significant differences with respect to seed yield of green gram.

Cotton crop is the main *kharif* crop in irrigated middle-western plain of Gujarat. Losses in seed cotton yield due to the presence of unwanted plants called weeds. Generally, pre emergence and post-emergence herbicides were used for control of weeds but it needs proper time and skill. The combination of pre and post emergence herbicides is required to be integrated for effective weed control to increase seed cotton yield. For better establishment of crop stand, well pulverized seed bed plays an important role. Tillage is considered as most effective and efficient technique for preparation of seed bed and to control the weeds. Conservation tillage practices are the alternatives which accumulate organic matter in the soil surface, enhance water absorption capacity, improve soil physical, chemical and biological properties increased cotton yields after 6-8 years of application (Boquet *et al.* 2004). Similarly, Burmester *et al.* (1993) indicated that there is no ploughing in Zero Tillage (ZT), soil become compact and may restrict the growth of root, which ultimately reduce cotton yield. This compact layer usually develops at a depth of six inches or less on the heavy textured soils when ZT is applied. Generally before sowing of cotton, seed bed prepared and then application of pre emergence herbicides are common practices adopted for weed control. Such type of practices may not be effective in controlling the weeds in cotton hence, an alternate approach need to be practice. Combination of various tillage viz., zero tillage conservation tillage, minimum tillage etc. along with some promising post emergence herbicide may provide the effective control of weeds which help in improve the yield and quality of cotton.

MATERIALS AND METHODS

A field experiment was conducted at research farm of AICRP- Weed Management, Anand Agricultural University, Anand (Gujarat) during the *kharif-rabi* season of 2016-2017. The soil of the experimental field was sandy loam in texture with pH of 7.80 and EC of 0.17 dS m^{-1}. Initial soil analysis indicated the organic carbon, available nitrogen, phosphorus and potash of the soil ranged to 0.27 per cent (low), 342.0 (low), 48.0 (medium) and 298.0 (medium) kg/ha, respectively. The experiment was conducted in Strip plot design wherein, cotton was grown as *kharif* and *rabi* season while green gram grown as summer. In the first crop the treatments were T_1: Conventional tillage (CT), T_2: Conventional tillage (CT), T_3: Zero tillage (ZT), T_4: Zero tillage (ZT) and T_5: Zero tillage + Residue (ZT) were relegated to main plot while W_1: Pendimethalin 900 g/ha PE *fb* IC+HW at 30 & 60 DAS, W_2: Quizalofop ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS and W_3: IC + HW at 15, 30 and 45 DAS as subplot treatment. While in second crop the treatments were T_1: Conventional tillage (CT) followed by Conventional tillage, T_2: Conventional tillage (CT) followed by Zero tillage (ZT), T_3: Zero tillage (ZT) followed by Zero tillage (ZT), T_4: Zero tillage (ZT) followed by Zero tillage + Residue (ZT + R) and T_5: Zero tillage + Residue (ZT) followed by Zero tillage + Residue (ZT) relegated to main plot while W_1: Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS, W_2: Imazethapyr @ 75 g/ha PoE *fb* IC+HW at 30 DAS and W_3: IC + HW at 20 & 40 DAS as subplot treatment.

The cotton cultivar G. Cot. Hy. 8 (BG II) was sown keeping the seed rate of 4.0 kg/ha at a distance of 120 cm row to row and 45 cm plant to plant. The crop was fertilized with 280 kg N/ha supplied through urea only. One fourth quantity of nitrogen (70 kg/ha) was applied as a basal and remaining quantity of nitrogen was applied in equal split at different growth stages of cotton *viz.*, square formation, flowering and boll formation stages as top dressing. Succeeding greengram cultivar GAM 5 was sown keeping the seed rate of 20.0 kg/ha at a distance of 45 cm row to row. The crop was fertilized with 20 kg N/ha and 40 Kg P_2O_5. Entire quantity of nitrogen and phosphorous were supplied through urea and single super phosphate as basal dose, respectively. The herbicides were applied as per the treatment in respective crop by knapsack sprayer fitted with flat-fan nozzle using 500 l/ha water. All the recommended package of practices was followed to grow cotton and green gram crop. Observations of weed density and weed dry biomass were recorded in both the crops using one meter square size quadrate. Weed control efficiency (WCE) was calculated on the basis of standard formula as suggested by Maity and Mukherjee (2011). Soil samples (initial & at harvest) were collected and analyzed to study different microbiological properties *viz.,* total bacterial, fungal actinobacteria, diazotrophs and

PSM count and soil dehadrogenase activity.

RESULTS AND DISCUSSION

Cotton crop

Effect of tillage practices : Data presented in Table 1 indicated that weed density and dry biomass (11.0/m^2 and 31.1 g/m^2) of total weed recorded significantly the highest under zero tillage and zero tillage + residue treatments, respectively at harvest. Similarly, Usman *et al.* (2013) also revealed that zero tillage and reduced tillage was recorded higher weed density as compared to conventional tillage. The higher weed density in zero tillage might be due to higher weed seed bank within the top five centimeters of soil are also exposed to more favorable germination conditions (Chauhan *et al.*, 2012). While the lowest total weed and weed dry biomass was recorded under conventional tillage and zero tillage, respectively. Weed density and dry biomass of monocot weeds at harvest was found to be the highest under zero tillage + residue (8.0/m^2) while the lowest was observed under conservation tillage treatment. Whereas, zero tillage and conventional tillage remain *at par* with each other but found significantly superior over other treatments for density and dry biomass of dicot weed.

Significantly the highest seed cotton yield was achieved under conventional tillage treatment (2.52 t/ha) while the lowest seed cotton yield (1.88 t/ha) was recorded under zero tillage practices (Table 1). Further, conventional tillage was found significantly superior over other treatments with respect to recording higher seed cotton yield. The higher yield under conventional tillage could be attributed to improved boll weight by increasing the amount of the soil that the plant roots could explore for water and nutrients (Rosolem *et al.* 2002). Further, Schwab *et al.* (2002) indicated that conventional tillage might have eliminated compaction of sub-surface soil due to deep tillage, which may enhanced root growth and subsequent nutrient and water uptake thereby produced higher seed cotton yield. Stalk yield was found non significant due to different tillage treatment. However, maximum and minimum stalk yield was recorded under conventional tillage + conventional tillage and zero tillage + residue treatment, respectively.

Effect of weed management practices : Significantly the lowest density monocot and sedges were recorded under IC + HW at 15, 30 and 45 DAS. Significantly the lowest dicot and total weeds recorded under quizalofop ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS at harvest. Weed dry biomass of monocot, dicot and total were recorded significantly the lowest under IC + HW carried out at 15, 30 and 45 DAS except for dicot weed it was *at par* with application of pendimethalin 900 g/ha PE *fb* IC+HW at 30 and 60 DAS. Application of broad spectrum herbicide pendimethalin might have effectively reduced the germination of weed seeds and lower down the weed flora of monocot and dicot weeds effectively, whereas, hand weeding carried out at 30 and 40 DAS might have controlled later germinated weeds. Thus, integrated effect of this treatment resulted in reducing weed density and dry weight below the critical level of competition. These results are in agreement with those reported by Prabhu *et al.* (2012) and Patel *et al.* (2013). Least dry weight of sedges was recorded

Table 1, Weed density and weed dry biomass as well as seed cotton yield as influenced by tillage and weed management practices in cotton

Treatments	Weed density (No/m²) at harvest				Weed dry biomass (g/m²) at harvest				Seed cotton yield (t/ha)	Stalk yield (t/ha)
	Monocot	Dicot	Sedges	Total	Monocot	Dicot	Sedges	Total		
Tillage & crop residue management practices in cotton (T)										
T_1: CT - CT	5.54(30.7)	5.63(32.4)	2.23(4.11)	8.22(67.2)	23.7(569)	8.69(108)	3.41(13.2)	25.9(690)	2.52	5.14
T_2: CT - ZT	7.00(51.8)	6.38(44.9)	3.16(9.33)	10.2(106)	25.6(703)	8.48(84.2)	4.80(27.3)	27.5(815)	2.48	5.13
T_3: ZT - ZT	7.44(55.3)	7.25(56.2)	3.04(8.78)	11.0(120)	23.7(642)	6.71(49.1)	2.31(4.52)	25.0(695)	1.88	4.90
T_4: ZT - ZT+R	7.77(59.1)	5.46(30.6)	2.72(6.56)	9.82(96.2)	30.4(949)	4.79(25.5)	3.06(10.4)	31.1(985)	1.95	4.36
T_5: ZT+R - ZT+R	8.00(64.4)	6.20(41.3)	2.94(7.89)	10.7(114)	22.4(572)	4.23(17.0)	2.65(6.84)	23.1(596)	2.19	4.98
S. Em. ±	0.21	0.20	0.13	0.18	0.92	0.16	0.08	0.90	0.051	0.16
CD (P=0.05)	0.51	0.64	0.42	0.60	2.99	0.50	0.27	2.92	0.17	NS
CV (%)	6.9	9.5	13.7	5.5	10.9	7.1	7.7	10.2	6.9	10.0
Weed management practices in cotton (W)										
W_1: Pendimethalin 900 g/ha PE *fb* IC+HW at 30 & 60 DAS	7.24(52.5)	7.57(57.6)	3.21(9.67)	10.9(120)	23.2(570)	5.65(36.0)	4.53(23.0)	24.5(629)	2.33	5.08
W_2: Quizalofop ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS	7.77(60.5)	3.92(14.5)	3.00(8.20)	9.07(83.2)	32.7(1086)	8.48(102)	2.31(5.14)	34.4(1194)	2.12	4.47
W_3: IC + HW	(43.7)	7.07(51.2)	2.25(4.13)	9.94(99.1)	19.5(405)	5.62(31.8)	2.90(9.24)	20.5(446)	2.17	5.16
at 15, 30 and 45 DAS	6.61									
S. Em. ±	0.20	0.51	0.04	0.16	0.95	0.11	0.06	0.90	0.05	0.07
CD (p=0.05)	NS	0.20	0.14	0.62	3.75	0.44	0.23	3.57	NS	0.27
CV per cent	12.6	3.2	4.8	6.1	14.6	6.6	7.2	13.3	8.2	5.4
Interaction M x W	0.80	0.98	0.29	0.93	4.51	0.73	0.53	4.47	NS	NS
CV (%)	7.0	9.2	5.8	5.4	10.4	6.4	9.4	9.7	9.6	5.4

Note: Data subjected to Ö(X+1) transformation. Figures in parentheses are means of original values.

under application of quizalofop ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS at harvest.

Significant differences in seed cotton yield were not found due to different weed management practices. However, maximum and minimum seed cotton yield was recorded under application of pendimethalin 900 g/ha PE *fb* IC+HW at 30 and 60 DAS and IC+ HW at 15, 30 and 45 DAS, respectively. The higher yield under said treatment might be due to the season long weed control which provide congenial condition for better growth and enhanced leaf area contributing for the activated photosynthesis and translocation of more photosynthates to sink which resulted in increase the yield. Malarko *et al.*, (2017) also reported that pre emergence application of pendimethalin at 1.0 kg/ha + power weeding on 40 DAS recorded higher seed cotton yield. With respect to stalk yield, significantly higher stalk yield w as recorded under IC + HW at 15, 30 and 45 DAS treatment while the lowest was recorded under quizalofop ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS.

Greengram Crop

Effect of tillage practices : Total weed density and dry biomass was recorded significantly the highest under zero tillage followed by zero tillage + residue (12.0/m^2) and zero tillage followed by zero tillage (12.5 g/m^2), respectively. Conflicting findings regarding the impact of conventional tillage on weed population

Table 2. Weed density, weed dry biomass, *Rhizobium* nodules dry biomass, seed and haulm yield as influenced by tillage and weed management practices in green gram

Treatments	Weed density (No/m^2) at30 DAS	Weed drybiomass (g/m^2) at 30 DAS	Nodule dry biomass (mg/plant) at 35 DAS	Seed yield (kg/ha)	Haulm yield (kg/ha)
T_1: CT - CT	7.19(53.0)	6.90(47.8)	54.4	587	927
T_2: CT - ZT	10.9(126)	9.12(94.9)	55.6	547	898
T_3: ZT - ZT	10.0(118)	12.5(156)	56.4	551	901
T_4: ZT - ZT+R	12.0(157)	10.2(107)	58.6	560	923
T_5: ZT+R - ZT+R	8.38(73.9)	9.02(81.1)	60.0	677	1064
S. Em. ±	0.29	0.18	1.08	20.8	18.7
CD (p=0.05)	0.93	0.60	3.45	67.7	60.9
CV (%)	8.8	5.8	5.7	10.7	5.94
W_1: Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS	8.82(82.1)	9.68(97.4)	51.7	720	1112
W_2: Imazethapyr 75 g/ha PoE *fb* IC+HW at 30 DAS	13.4(187)	9.16(89.6)	50.8	413	718
W_3: IC + HW at 20 & 40 DAS	6.96(48.3)	9.83(105)	68.6	620	998
S. Em. ±	0.17	0.14	1.18	9.84	7.40
CD (p=0.05)	0.69	NS	3.78	38.6	29.0
CV (%)	6.96	5.84	8.8	6.52	3.04
Interaction M x W	1.12	0.67	NS	NS	NS

Note: Weed data subjected to Ö(X+1) transformation. Figures in parentheses are means of original values.

dynamics wherein, several studies have found that tillage can have both a negative and positive effect on weed seed banks as tillage may temporarily incorporate some weed seeds into deeper layers while bringing others to the soil surface where they are exposed to the conditions necessary for germination (Carter and Ivany, 2006). Hence, the variable results were observed with respect to various tillage practices in suppression of density and dry weight of weeds in cotton-greengram cropping system. Conventional tillage followed by conventional tillage practices performed better by recording significantly the lowest density of monocot, dicot, sedges and total weeds except for monocot weeds which was *at par* with zero tillage followed by zero tillage + residue and for dicot weeds zero tillage. Similarly, dry weight of monocot, sedges and total weeds was also recorded significantly the lowest under conventional tillage followed by conventional tillage practices, while dry weight of dicot weeds was recorded significantly lower under zero tillage followed by zero tillage + residue as compared to rest of the treatment except zero tillage + residue followed by zero tillage + residue.

Further, it was observed that tillage and crop residue treatment significantly influenced on dry biomass of nodules due to tillage operation. Significantly higher dry biomass of nodules was recorded under zero tillage + residue followed by zero tillage + residue treatment as compared to rest of the treatment except zero tillage followed by zero tillage + residue treatment. The higher dry biomass of root nodules under said treatment might be due to

Table 3. Effect of tillage and weed management practices on soil microbial properties (at harvest) under cotton-greengram cropping system (cotton)

S. No.	Treatment	Total Bacteria(10^7 CFU/g soil) Initial: 90 x 10^5	Fungi (10^4 CFU/ g soil) Initial: 58 x 10^3	Actinobacteria (10^4 CFU/ g soil) Initial: 70 x 10^3	Total Diazotrophs (10^3 CFU/g soil) Initial: 65 x 10^3	Total PSM (10^3 CFU/ g soil) Initial: 65 x 10^3	Dehydrogenase (µg TPF/ g soil/24 h) Initial: 19
Tillage & crop residue management practices in cotton (T)							
T_1	CT - CT	11.4	11.1	10.4	98.3	98.3	23.9
T_2	CT - ZT	11.4	11.0	10.4	98.0	98.9	23.8
T_3	ZT - ZT	11.5	11.1	10.6	99.0	101	24.1
T_4	ZT - ZR+R	14.5	14.1	11.6	100	103	24.9
T_5	ZT+R - ZT+R	14.5	14.1	11.7	101	106	25.0
	S.Em.+	0.35	0.25	0.19	0.79	1.68	0.26
	CD (p=0.05)	1.12	0.786	0.601	2.52	5.36	0.825
	CV (%)	8.3	6.0	5.1	2.4	5.0	3.2
Weed management practices in cotton (W)							
W_1	Pendimethalin 900 g/ha PE *fb* IC+HW at 30 & 60 DAS	12.6	12.2	10.9	99.0	101	24.2
W_2	Quizalofop ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS	12.5	12.2	10.9	98.7	100	24.0
W_3	IC + HW at 15, 30 and 45 DAS	12.9	12.5	11.0	101	104	24.8
	S.Em.+	0.05	0.10	0.09	0.85	0.92	0.26
	CD (p=0.05)	0.162	NS	NS	NS	NS	0.487
	CV (%)	1.7	3.3	3.6	3.6	3.9	2.7
	Interaction T x W	NS	NS	NS	NS	NS	NS

Table 4. Effect of tillage and weed management practices on soil microbial properties (at harvest) and nodule dry weight under cotton-greengram cropping system (greengram)

S. No.	Treatment	Total Bacteria(10^7 CFU/g soil) Initial: 90 x 10^5	Fungi (10^4 CFU/ g soil) Initial: 58 x 10^3	Actinobacteria (10^4 CFU/ g soil) Initial: 70 x 10^3	Total Diazotrophs (10^3 CFU/g soil) Initial: 65 x 10^3	Total PSM (10^3 CFU/ g soil) Initial: 65 x 10^3	Dehydrogenase (µg TPF/ g soil/24 h) Initial: 19	Nodule/ Plant at 50 DAS Initial	Nodule dry weight (mg/plant) at 50 DAS Initial
Tillage & crop residue management practices in greengram (T)									
T_1	CT - CT	83.8	57.8	10.8	94.7	95.0	18.1	13.7	55.4
T_2	CT - ZT	84.4	60.4	10.9	95.0	95.7	19.4	13.9	56.6
T_3	ZT - ZT	85.8	62.9	11.1	95.3	96.9	20.7	14.1	57.4
T_4	ZT - ZR+R	101	70.9	12.4	97.0	101	21.1	14.7	58.6
T_5	ZT+R - ZT+R	103	75.1	12.8	99.4	103	22.6	17.1	61.0
	S.Em.+	2.77	2.29	0.10	0.87	1.07	0.65	0.38	1.10
	CD (p=0.05)	8.86	7.34	0.315	2.77	3.42	2.08	1.22	3.51
	CV (%)	9.1	10.5	2.5	2.7	3.3	9.6	7.8	5.7
Weed management practices in greengram (W)									
W_1	Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS	89.6	64.5	11.6	95.9	98.3	19.5	13.5	52.5
W_2	Imazethapyr @ 75 g/ha PoE *fb* IC+HW at 30 DAS	89.6	62.7	11.4	95.3	97.6	19.6	13.0	51.7
W_3	IC + HW at 20 & 40 DAS	95.8	69.1	11.9	97.7	99.7	22.0	17.6	69.2
	S.Em.+	1.72	1.14	0.13	0.86	0.87	0.49	0.30	1.17
	CD (p=0.05)	5.51	3.66	NS	NS	NS	1.58	0.97	3.76
	CV (%)	8.0	7.4	4.6	3.8	3.7	10.3	8.8	8.6
	Interaction T x W	NS	NS	NS	NS	NS	NS	NS	NS

higher number of nodules/plant recorded under said treatment.

Different tillage practices showed significant differences with respect to seed yield of green gram. Significantly the highest seed and haulm yields were recorded under zero tillage + residue followed by zero tillage + residue treatment whereas, significant differences among other treatment were not found.

Effect of weed management practices : Weed dry biomass recorded at 30 DAS was unaffected due to different weed management practices (Table 2). Though the numerical lower dry weed biomass was recorded under application of imazethapyr 75 g/ha POE *fb* IC + HW at 30 DAS followed by pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS.

Similarly, different weed management practices also showed significant variation in nodules dry biomass. Significantly the highest dry biomass of nodules (68.6 g/plant) was recorded under IC+HW at 20 and 40 DAS. **Brahmbhatt (2014)** also reported that IC + HW carried out at 20 and 40 DAS was recorded significantly higher dry weight of *Rhizobium* nodules in blackgram at 45 DAS as compared to application of imazethapyr at 100 g/ ha as PoE. Among herbicidal treatment both the treatment remain *at par* with each other with respect to dry biomass of nodules/plant. Application of pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS recorded significantly the highest seed (720 kg/ ha) and haulm (1112 kg/ha) yields. The higher yield may be due to effective weed control which resulted in increased the yield attributes and thereby yield. Jinger *et al.*, (2016) also observed similar kind of results due to integration of pendimethalin. While application of imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS recorded significantly the lowest seed (413 kg/ha) and haulm (718 kg/ha) yields.

Effect on microbial properties : Among different microbial properties, all of them were found significantly influenced by tillage practices (Table 3 and 4). Significantly the highest improvement in soil microbial properties was recorded in treatments receiving zero tillage with residue incorporation. Additionally, zero tillage + residue treatment showed maximum increase in all microbial properties in comparison to initial properties, numerically.

In case of weed management practices, total bacterial population, total fungi and soil DHA were significantly influenced by weed management practices except, actinobacterial, diazotrophs and PSM population at harvest. Treatments for which, interculturing and hand weeding operations were performed at 20 and 40 DAS showed significant improvement in microbial properties in comparison with treatments receiving application of herbicides at harvest. In comparison to initial, there was an increase in soil microbial activities. The interaction effect of tillage and weed management practices found non-significant for all microbial properties.

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Production performance and market integration of cotton markets in India

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ABSTRACT : The present study has been undertaken to work out the trends in area, production and productivity of cotton in country and to analyze the integration among major cotton markets based on secondary data. The analysis revealed that production and productivity of cotton was consistently increasing significantly over the years at global, national and state level. India was leading among all the cotton growing countries in the world regarding the area under cotton and it was the second largest producer of cotton next to China. In the state wise analysis, the increase in production of cotton in Andhra Pradesh was found to be the highest at a CAGR of 9.11 per cent followed by Madhya Pradesh (6.21 %) and Maharashtra (5.28 %) and lowest was observed in Tamil Nadu (0.81 %). The variability, both in area and productivity in different states of India contributed towards variability of cotton output in the country. In all the study markets, a strong positive trend was observed in the prices of cotton during the last decade. All the selected cotton markets in the state and country were found to be integrated and exhibited long run relationship with each other. Adilabad market was found to be the lead cotton market as it was influencing most of the other selected cotton markets in country. Further, the co-integration test for the lead cotton market and lint in domestic and international markets indicated that influence of international market (USA) is transmitted to Indian cotton markets through its impact on lint prices in the domestic market.

***Key words* :** Compound annual growth rate, cotton, market integration, seasonal indices, trends

Government initiatives like the Technology Mission on Cotton and Technology Up gradation Fund Scheme have improved the marketability of the farm produce and helped in modernizing and upgrading the ginning and pressing factories. These initiatives have led to appreciable improvement in the quality of cotton bales, which in turn have proven beneficial for the textile industry. Furthermore, grow-ing disposable incomes have also accelerated domestic consumption, increasing demand within the country as well. The selected markets at national level were Adoni (Andhra Pradesh), Adilabad (Andhra Pradesh), Akot (Maharashtra), Rajkot (Gujarat), Sendhwa (Madhya Pradesh) and Sirsa (Haryana).

There are several impediments to the efficient functioning of any market in a developing economy like India (Beag and Singla 2014). In case of cotton, there are considerable seasonal price variations as well as regional price variations. However, one way to throw some light on this issue is to analyze the market performance by studying market integration (Mukhtar and Javed 2007). The market integration can be measured in terms of strength and speed of price transmission between markets across various regions of the country (Ghafoor *et al.,* 2009). The degree, to which consumers and producers would benefit, depends on how domestic markets are integrated with world markets and how different regional markets are integrated with each other (Varela *et al.,* 2012).

The present study an attempt was made to investigate the behavior of cotton prices as well as the co integration of national and regional cotton markets.

I Trends in area, production and productivity of cotton in India : The data on area under cotton, production and productivity in India has been presented in Fig. 1. The CAGR with respect to these variables are given in Table 1. The area under cotton in India has increased from 58.80 lakh ha in 1950-1951 to 76.1 lakh ha in 1970-1971, declined to 74.40 lakh ha in 1990-1991 and again increased to 112.40 lakh ha in 2010-2011. The highest area under cotton was recorded in the year of 2011-2012 at 121.8 lakh ha. The area under cotton in India increased significantly during 1960s, 1990s and 2000s with CAGR of 3.04 per cent, 2.7 and 2.29 per cent, respectively. However, the CAGR of area under cotton was found to be negative and non-significant during the period of 1960s and 1980s and the same was positive but non-significant during the period of 1970s. Overall, during 1950-51 to 2016-2017 the area under cotton in India increased significantly with positive CAGR of 0.49 per cent.

The cotton productivity in India increased with significant CAGR of 2.99 per cent during the study period (1950-1951 to 2016-2017). Productivity of cotton in India increased from 87.89 kg/ha in 1950-1951 to 610.36 kg/ha in 2016-2017. The increase in productivity was by about 6.94 times might be due to the technological changes occurred in the cotton cultivation over this period. The productivity rise of 200 kg/ha was observed from 2000-2001 to 2005-2006 which might be attributed wide spread adoption to the start of *Bt* cotton in India. The productivity of cotton in India increased with highest CAGR (8.12%) in 2000s at 8.12 per cent followed by 1980s, 1970s and 2000s with CAGR of 4.09, 3.30 and 2.53 per cent respectively. The CAGR of cotton productivity was non-significant in 1950s and 1960s.

The data presented in the Fig. 1 depicts that the production of cotton in India has increased from 30.40 lakh bales in 1950-1951 to 373.66 lakh bales in 2016-2017. The increase in production was approximately 12.29 times which was due to the increase in area and productivity of cotton in India throughout the study period. The CAGR of production in 2000s was observed to be highest during the study period which was due to significant increase in area and productivity of cotton during this period. The CAGR of production of cotton in India was significant in all decades except 1960s and 1980s. The non-significant increase in area and productivity of cotton was in 1960s resulted in insignificant increase in cotton production in India. The negative CAGR of area under cotton during 1980s was main reason behind the insignificant increase in cotton production in

India during this period. During 1970s, despite insignificant change in area under cotton in country, the increase in productivity in a major (CAGR 3.68%) was resulted into the significant increase in the cotton production.

The results of analysis of variability of area, production and productivity were presented in Table 1. As expected, variables that exhibited high growth rate were highly instable as evident from the instability index. This was more pronounced during the 1990s, 2000s and 2010s in productivity variability with an index of 11.64, 9.81 and 9.51 per cent respectively. The production instability index of cotton exhibited high variability in 1980, 1950s, 1980s and 2000s with variability of 15.96, 11.96, 10.45 and 10.08 per cent respectively. The variability of area was highest in 1950s at 6.19 per cent followed by 2010s (5.75%) and 1980s (4.93). The overall variability of area, production and productivity from 1951 to 2014 was 11.08, 25.94 and 17.06 per cent, respectively.

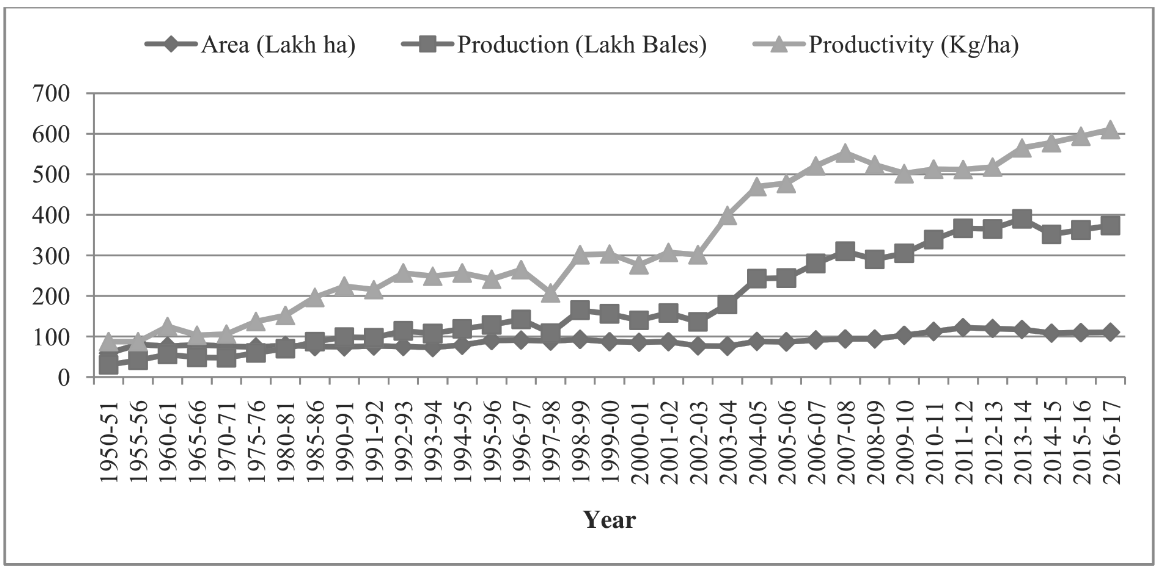

Fig 1. Trends in area, production and productivity of cotton in India

Table 1. Compound annual growth rate and variability of area production and productivity of cotton in India, 1950-51 to 2016-17

Year	CAGR (%)			Variability (%)		
	Area	Production	Productivity	Area	Production	Productivity
1951-1960	3.04***	4.29**	1.23	6.19	11.96	7.56
1961-1970	-0.13	0.29	0.44	3.02	6.56	6.32
1971-1980	0.42	3.68**	3.3**	4.38	10.45	8.31
1981-1990	-1.26	2.79	4.09**	4.93	15.96	11.64
1991-2000	2.7***	5.31***	2.53*	4.78	9.84	9.81
2001-2010	2.29**	10.67***	8.12***	5.75	10.08	9.51
2011-2017	1.12	4.23**	3.21	2.71	1.76	3.47
1951-2017	**0.49*** **	**3.51*** **	**2.99*** **	**11.08**	**25.94**	**17.06**

***, ** and * significant at 1, 5 and 10 per cent level of significance

II Area, production and productivity of cotton in different states : Cotton is grown throughout India, encompassing a wide range of agronomic and climatic regions. The main cotton growing states of India are Maharashtra, Gujarat, Andhra Pradesh, Haryana, Punjab, Rajasthan, Karnataka and Tamil Nadu. The details on average area, production and productivity of cotton in India for tri-annum 2014-2015 to 2016-2017 are furnished in figure 2. During TE 2016-2017, the area under cotton in India was found to be 120.38 lakh hectares. Among the states, Maharashtra with an average of 41.54 lakh hectare has the maximum share of 34.51 per cent in national area, followed by Gujarat (22.09 %), Andhra Pradesh (18.46 per cent), Madhya Pradesh (5.06 per cent), Haryana (4.95 %), Karnataka (4.70 per cent), Punjab (4.11 %), Rajasthan (3.63 %), Tamil Nadu (1.14 %) and Odisha (0.95 %).

The data presented in Fig. 2 showed that the average production cotton during TE 2016-2017 at national level was 351.07 lakh bales. The highest producer of cotton in the country was found to be Gujarat with tri annum average of 103.33 lakh bales which contributed 29.43 per cent towards national cotton production followed by Maharashtra at 78.96 lakh bales with 22.49 per cent share in national production. Andhra Pradesh produced 64.02 lakh bales accounting for 18.23 per cent share in national production. Other major cotton producing states were Haryana, Punjab and Madhya Pradesh with respective contribution of 7.07, 5.95 and 5.63 per cent in national cotton production.

It is evident from the figure 2 that average productivity of cotton during TE 2016-2017 ranged between the highest at 718.89 kg/ha in Punjab to the lowest at 322.95 kg/ha in Maharashtra. Beside Punjab, the higher levels of productivity were recorded at 708.36 kg/ha in Haryana followed by Gujrat at 685.75 kg per ha, Tamil Nadu at 565.18 kg per ha and Madhya

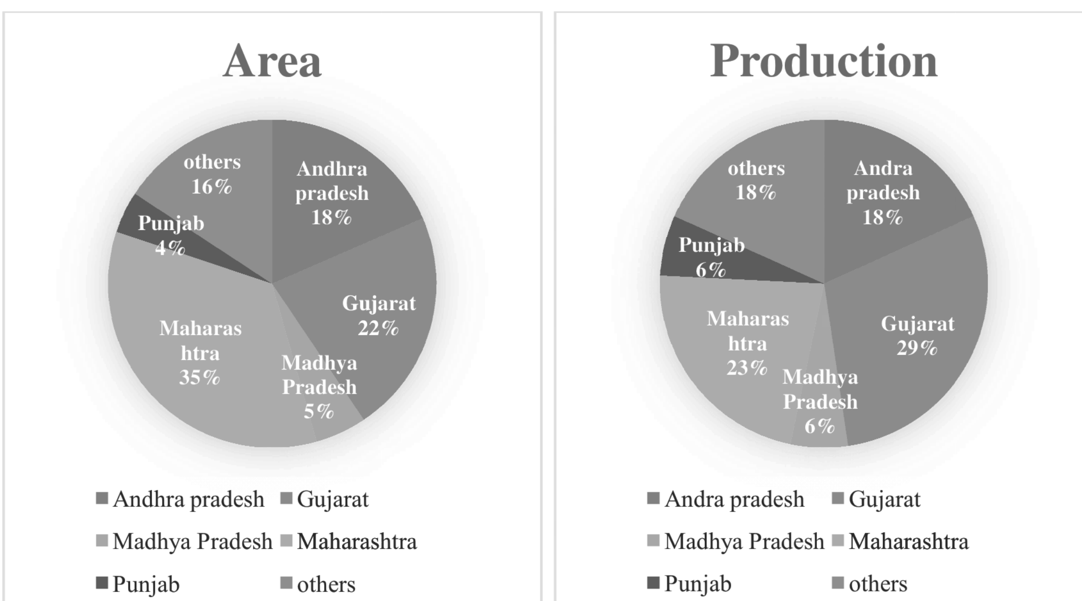

Fig 2. Relative share of area and production of cotton of different states in India

Pradesh at 556.29 kg/ha. On the other hand, besides Maharashtra, relatively low productivity levels were also observed in states like Karnataka (429.87 kg/ha) and Andhra Pradesh (486.31 kg/ha).

III Compound annual growth rate and variability of area, production and productivity of cotton in different states of India : The compound annual growth rates (CAGR's) and variability of area, productivity and production of major cotton growing states of India has been provided in Table 2. Over the period of about four decades (1971 to 2017), the decade wise CAGR of area in Andhra Pradesh increased significantly except in the period of 1970s. On the contrary all the decadal growth rates were negative and insignificant for the area under cotton in Karnataka. The CAGR of area under cotton in Gujarat during the period of 1990s and 2000s was 6.00 and 6.15 per cent, respectively with the remaining all decades showing a non significant and negative growth rate except 1970s where it was positive but non-significant.

The highest growth rate of area under cotton in Haryana was observed during 1980s at 3.43 per cent followed by the period 1970s at 3.43 per cent and 1990s at 2.27 per cent and negative growth rate was observed during 2000s. The CAGR of area under cotton in Maharashtra was significant during 1990s and 2000s with the growth rates of 2.67 and 1.54 per cent respectively while rest of all the decades was observed to be exhibiting negative growth rate. Similarly in Rajasthan CAGR of area under cotton was significant during the period of 1970s at 4.14 per cent and 1990s at 4.52 per cent and rest of all decades were negative and non-significant. The CAGR of area under cotton for all the decades in Madhya Pradesh (except 2000s with a CAGR of 1.69%), Punjab (except 1970s with a CAGR of 4.53 per cent) and Tamil Nadu (except 2011-17 with a CAGR of 3.59 percent) were reported to be non-significant. The overall CAGR of area under cotton was found to be highest in Andhra Pradesh at 4.36 per cent followed by Haryana (2.36 %), Gujarat (0.99 %), Maharashtra (0.99 %) and Rajasthan (0.74 %). The states like Karnataka, Madhya Pradesh, Punjab, and Tamil Nadu were found to be exhibiting overall negative growth rate of area under cotton.

The CAGR of productivity of cotton was reported to be significant in Andhra Pradesh during the period of 1970s and 2000s with the growth rate of 14.31 and 5.56 per cent/annum respectively while negative CAGR of productivity was observed during 1980s and 1990s. The growth rate of productivity increased significantly in Haryana during 2000s at 11.00 per cent and in 2011-2017 at 4.45 per cent respectively whereas negative growth rate was found in the period of 1990s. The CAGR of productivity of cotton in Madhya Pradesh was found to be significant during 1980s at 17.79 per cent and in 1990s at 8.87 per cent while the CAGR was negative in the period of 2000s. The CAGR of productivity of cotton in Gujarat exhibited significant growth rate during the period of 2000s at 12.23 per cent and 1990s at 5.51 per cent whereas the growth rate was found to be negative in 1980s. The CAGR of productivity of cotton in Karnataka was found to be highest during the period of 2011-2014 at 22.10 per cent followed by 2000s at 8.50 per cent and 1970s at 5.52 per cent whereas negative growth rate was observed in 1990s. The growth rate of

Table 2. Compound annual growth rate and variability of area, production and productivity of cotton in different states of India, 1971 to 2017.

Year	State	CAGR (%)			Variability (%)		
		Area	Production	Productivity	Area	Production	Productivity
1971-1980	Andhra Pradesh	2.15	14.65**	14.31**	14.87	34.15	29.73
1971-1990		4.23**	-1.54	-5.05	11.31	22.44	20.67
1991-2000		6.90***	3.37*	-3.22	11.99	12.86	15.11
2001-2010		4.73**	10.54***	5.56***	13.76	13.72	8.14
2011-2017		8.44*	12.56	1.79	6.27	9.91	5.42
1971-2017		4.36***	9.11***	4.59***	18.33	27.73	25.75
1971-1980	Gujarat	0.23	1.38	0.43	5.22	14.74	13.47
1971-1990		-5.09	-6.69	-1.68	13.58	30.89	28.42
1991-2000		6.00***	11.85***	5.51**	9.61	19.17	16.41
2001-2010		6.15***	18.91***	12.23***	5.50	17.88	18.80
2011-2017		-1.04	0.97	2.22	6.15	10.87	5.93
1971-2017		0.99***	5.14***	4.09***	26.32	52.07	29.47
1971-1980	Haryana	3.43***	4.57***	0.32	6.58	7.31	4.50
1971-1990		3.47**	2.2	1.09	10.24	13.65	14.73
1991-2000		2.27*	-4.08	-6.24	8.14	15.46	14.85
2001-2010		-1.95	8.80***	11.00***	7.50	17.49	17.41
2011-2017		3.84	10.8	4.45*	8.88	14.30	3.61
1971-2017		2.36***	3.49***	1.10***	14.96	22.51	26.72
1971-1980	Karnataka	0.31	6.62**	5.52**	10.09	19.68	12.93
1971-1990		-6.47	5.69	1.38	20.85	28.99	24.19
1991-2000		-0.4	-1.82	-1.45	7.02	10.15	9.51
2001-2010		-2.45	5.66	8.50***	17.91	24.24	11.80
2011-2017		1.26	24.75***	22.10***	7.03	8.69	0.90
1971-2017		-2.14	1.72***	4.17***	20.07	33.67	28.79
1971-1980	Madhya Pradesh	-0.71	0.23	0.21	5.22	23.55	23.37
1971-1990		-1.23	1.998	14.79***	14.51	44.12	17.36
1991-2000		-1.6	7.00*	8.67**	6.50	22.48	22.49
2001-2010		1.69**	-1.48	-2.77	5.21	7.30	8.16
2011-2017		-2.82	2.81***	5.7	4.84	1.15	5.59
1971-2017		-0.16	6.3***	6.21***	11.05	32.56	29.14
1971-1980	Maharashtra	-0.64	8.43**	8.40**	7.49	26.14	22.71
1971-1990		-0.33	2.85	3.38	2.04	26.88	17.36
1991-2000		2.67***	9.56**	6.86**	4.06	21.29	20.82
2001-2010		1.54**	13.69***	11.98***	5.34	15.54	16.04
2011-2017		-0.48	-0.98	-0.21	2.86	5.85	8.91
1971-2017		0.99***	5.28***	4.28***	8.88	31.19	27.60
1971-1980	Punjab	4.53***	4.11***	-1.12	4.49	6.90	2.75
1971-1990		0.49	9.54***	9.00**	13.15	20.38	19.17
1991-2000		-2.41	-12.97	-10.91	10.94	21.89	23.57
2001-2010		1.35	9.64**	8.18**	10.26	28.57	22.52
2011-2017		-2.94	5.03***	8.4	4.64	2.21	7.40
1971-2017		-0.13	0.83*	1.02**	15.81	33.25	31.20

1971-1980	Rajasthan	4.14**	7.69***	1.55	12.08	14.25	12.44
1971-1990		-0.63	4.18	4.85	10.58	34.68	29.15
1991-2000		4.52***	3.06**	-1.52	8.72	9.50	9.00
2001-2010		-1.41	2.43	4.24*	14.92	11.80	13.01
2011-2017		-3.38	10.72	14.21***	18.03	19.93	3.33
1971-2017		0.74***	3.47***	2.65***	23.00	29.06	23.06
1971-1980	Tamil Nadu	-0.45	3.49	3.2*	14.23	24.17	13.10
1971-1990		1.62	7.33**	5.61**	12.81	23.50	14.69
1991-2000		-2.32	0.51	2.13	7.59	5.66	11.84
2001-2010		-4.95	0.87	6.16***	24.61	16.99	8.39
2011-2017		3.59*	-16.99	-14.15	2.74	4.27	4.42
1971-2017		-2.26	0.81***	3.67***	20.33	23.28	16.99

***, ** and * significant at 1, 5 and 10 per cent level of significance

productivity in Maharashtra was seen to be highest in the period of 2000s at 11.98 per cent followed by 1990s at 9.56 per cent and 1970s at 8.43 per cent. The CAGR of productivity of cotton in Punjab significantly increased at 9.00 and 8.18 percent during 1980s and 2000s respectively whereas the growth rate was negative during the period of 1970s and 1990s. The CAGR of productivity of cotton in Rajasthan was significant in the period of 2000s at 4.24 per cent and in 2011-14 at 14.21 per cent while negative growth rate was observed during 1990s. The CAGR of productivity in Tamil Nadu was highest during the period of 2000s at 6.16 per cent followed by 1980s at 5.61 per cent and 1970s at 3.20 per cent and negative growth rate was observed from 2011-2017. The overall CAGR for the productivity of cotton found to be significant in all the states exhibiting the highest growth rate of 6.21 per cent in Madhya Pradesh followed by Andhra Pradesh (4.59%), Maharashtra (4.28%) and Gujarat (4.09%).

The CAGR of production in Andhra Pradesh was found to be highest during 1970s (14.65%) particularly due to the high contribution of increase in productivity in that period irrespective of the negative growth rate of area under cotton. It was followed by period of 2000s and 1990s with the growth rate of 10.54 and 3.37 per cent, respectively. Though the CAGR of area was significant in 1980s the CAGR of production was negative which was due to negative CAGR of productivity recorded in that period. Whereas in Gujarat the CAGR of production was observed to be highest in the period 2000s at 18.91 per cent followed by 1990s at 11.85 per cent and 1970s at 9.11 per cent. The negative growth rate of production in Gujarat during 1980s was due to the negative growth of both area and productivity in that period. The CAGR of production in Karnataka was significant in only two decades *i.e.*, 1970s (6.62%) and 2011-2017 (24.75%) which was due significant increase in production. Whereas the CAGR of production in Karnataka was non significant from 1980s to 2000s. The CAGR of production in Madhya Pradesh was significant during the period of 1990s at 7.80 per cent and 2011-2017 at 2.81 per cent. Though the growth rate of area in Madhya Pradesh during the period 2011-2014 was significant the CAGR of production was found to be negative which may be due to the negative growth rate of productivity in that period. The CAGR of production in Maharashtra was found to be highest in the period of 2000s at 13.69 per cent followed by 1990s at 9.56 per cent and 1970s at 8.43 per cent. Rajasthan has showed significant growth rate of production in during the period of 1970s at 4.14 per cent and in 1990s at 5.52 per cent while the remaining decades was hiving non-significant growth of production. The increase in production of cotton in Rajasthan during these two decades might be due to the increase in area under cotton in that period irrespective of negative growth rate in the productivity of cotton. Growth rate of cotton production in Punjab were significant for all the decades except 1990s which exhibited negative growth rate. The reason for the negative growth rate in 1990s the negative growth rate of both area and productivity of cotton in the state. On contrary Tamil Nadu production growth rate has been non-significant for all the decades except for the last four years with a CAGR of 3.59 per cent. The overall increase in CAGR of production of cotton was found to be significant for all the selected states with the highest growth rate of 9.11 per cent in Andhra Pradesh followed by Maharashtra (5.28 %) and Gujarat (5.14 %). The increase in CAGR of production of cotton was found to be lowest in Tamil Nadu (0.81%) and Punjab (0.83 %).

The results pertaining to the level of instability in area, productivity and production of cotton are given in Table 2. The overall variability in production of cotton for the period 1971 to 2017 was found to be highest in Gujarat (52.07%) and lowest in Haryana (22.51 %). In the decade wise analysis the variability in production of cotton was highest in Andhra Pradesh (34.15 %) during 1970s which was due to the high variability in productivity of cotton. During the same period low variability in production of cotton in Punjab (6.90%) was observed which was particularly due to the low variability in productivity of cotton. The variability in production of cotton has increased during 1980s in all the major cotton growing states except in Andhra Pradesh and Tamil Nadu. It ranged between 13.65 per cent in Haryana to 44.12 per cent in Madhya Pradesh. The increase in variability of production in all the states during this period was on the account of increase in variability of yield in cotton. The variability of production decreased during 1990s in all major cotton growing states except in Haryana and Punjab when compared to the previous decade. The variability of production was highest in Madhya Pradesh (22.48%) and lowest in Tamil Nadu (5.66%) during this period. The decrease in variability of cotton production during this period was mainly due to decrease in variability of area under cotton in all the cotton growing states. Further the variability in production of cotton increased in Andhra Pradesh, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu during 2000s. During this period, the increase in variability of production was caused particularly by the increase in variability of area under cotton in all the states except in Punjab and Haryana. In other hand, the variability of cotton production decreased in states like Gujarat, Madhya Pradesh and Maharashtra during 2000s. The decrease in variability of cotton production during this period was due decrease in variability of area in these states.

To summarize, it was observed that the trends in Area, production and productivity was consistently increasing over the years in global,

ABOHAR ⟷ ADILABAD, AKOT, ADONI, RAJKOT, SENDHWA, SIRSA

ADILABAD ⟷ ADONI

ADILABAD ⟶ AKOT, RAJKOT, SENDHWA, SIRSA

AKTOT ⟷ SIRSA

AKTOT ⟶ RAJKOT, SENDHWA, ADNONI

ADONI ⟷ SENDHWA

ADONI ⟶ SIRSA

RAJKOT ⟷ SENDHWA

RAJKOT ⟶ ADONI, SIRSA

SENDHWA ⟶ SIRSA

Fig 3. Market integration among major national cotton markets

national as well as in state level. The tri annum average analysis ending 2016-2017 revealed India was leading among all the cotton growing countries in the world regarding the area under cotton. In the same period it was it was also noticed that India was the second largest producer next to China. The significant variability both in area and productivity in different states of country are contributing to the variability of cotton output. Hence measures like evolving of improved varieties and dependable plant protection techniques may help in reducing variation of cotton output in the states/ country

IV market integration of cotton markets : The causal relationship between the prices series in major national cotton markets were approached through Granger Causality technique. The results of the analysis showing the relationship among major national cotton markets are presented below.

Among the major selected national cotton markets, the cotton price in Abohar market showed bidirectional causality in the price transmission with Adoni, Adilabad, Akot, Rajkot, Sendhwa and Sirsa cotton markets. Adilabad market showed bidirectional causality in price transmission with cotton market of Adoni and it had a unidirectional impact on the market prices of Akot, Rajkot, Sendhwa, and Sirsa. The Akot cotton market revealed a bidirectional causality with the Sirsa cotton markets, while, it had influenced the prices of the Adoni, Rajkot and Sendhwa cotton markets respectively in one way. The Akot cotton market itself was influenced by the prices of Adilabad market in unidirectional manner. The Adoni market showed a bidirectional causality in price transmission with the selected markets of Abohar, Adilabad and Sendhwa. It had also influenced the prices of Sirsa cotton market in

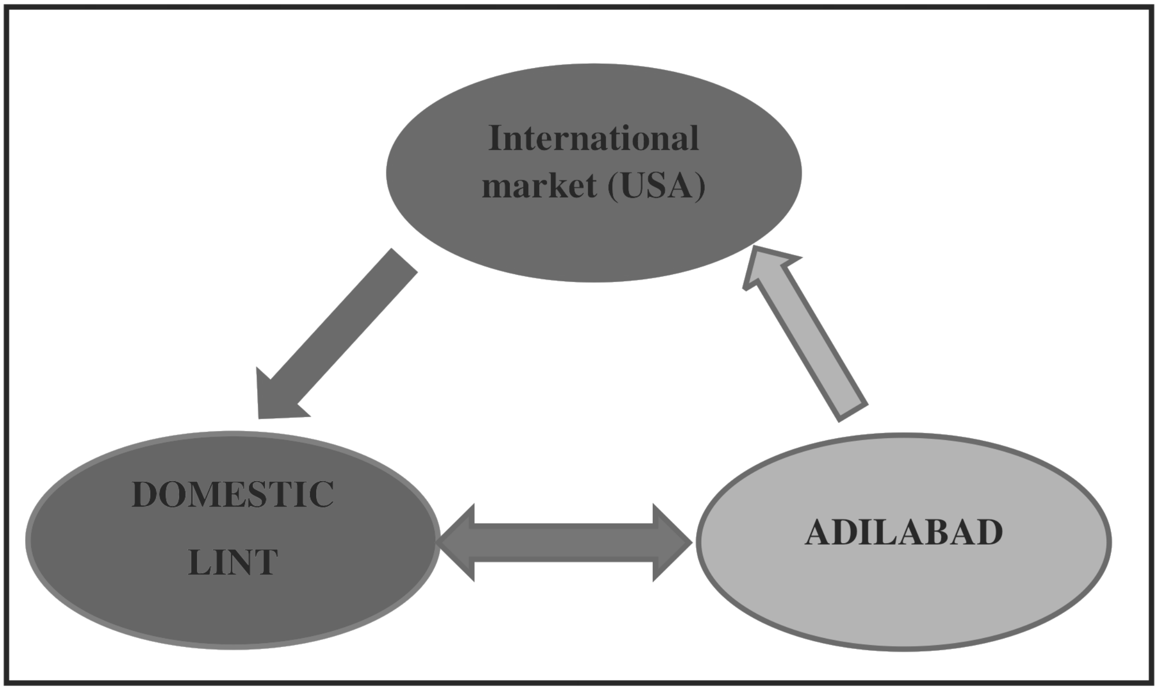

Fig 4. Market integration among national cotton markets, lint and international markets

one way. The Adoni cotton market itself was influenced by prices of Akot and Rajkot markets in a unidirectional manner. Rajkot cotton market exhibited bidirectional causality with the markets of Abohar and Sendhwa in price transmission. It also revealed a unidirectional relationship with the prices of Adoni and Sirsa markets. Rajkot cotton prices has been influenced by the cotton markets of Akot and Adilabad in unidirectional manner. Sendhwa cotton market exhibited unidirectional causality only with Sirsa cotton markets in the price transmission.

The data presented in Fig. 3 revealed that the Adilabad market influenced the prices of all the selected cotton markets in unidirectional manner at national level except Abohar and Adoni markets with which it exhibited bidirectional causality relationship. So Adilabad market was considered as lead cotton market among all the selected markets in India. Akot cotton market was influencing most of the other cotton markets in unidirectional manner after Adilabad market which can be considered as most influential market after Adilabad influencing cotton prices in different markets of country.

V Market integration among global cotton markets : The causal relationship among the cotton markets and lint in domestic and international markets were tested using Granger's Causality technique. The results of the analysis showing the relationship between national and international cotton markets are presented in figure 4. It has been observed that while USA market exhibited a unidirectional causality in price transmission to lint in the domestic market, it was also being influenced by the prices of Adilabad cotton market in a unidirectional manner. Indian lint in domestic market was found to be exhibiting a bidirectional causal relationship in price transmission with Adilabad cotton markets. Even though US cotton market has not directly influenced the prices of domestic cotton markets, it influenced the Indian lint prices which shared a bidirectional relationship with the national markets indicating influence of international market (USA) on Indian cotton markets through lint prices.

To summarize it has been found that the Grangers Causality Test revealed the presence of bidirectional relation with each other in cotton markets of Punjab. Further, the co-integration test for the selected cotton markets at national, international (USA) markets and cotton lint in domestic markets indicated that the cotton markets were integrated with each other and exhibited long run equilibrium. US cotton market has not directly influenced the prices of domestic cotton markets, it influenced the Indian lint prices which shared a bidirectional relationship with the national markets indicating influence of international market (USA) on Indian cotton markets through lint prices.

CONCLUSION

The significant variability both in area and productivity in different states of country are contributing to the variability of cotton output. Hence measures like evolving of improved varieties and dependable plant protection techniques may help in reducing variation of cotton output in the states/country. The study of selected markets in national level has shown that efficiency of marketing in the state has not as yet reached an optimal level as they are not spatially well integrated with one another in all the cases. The reasons for this might be poor market intelligence, absence of facility to transmit the information between the two markets instantaneously and poor physical infrastructure. The policy intervention calls for strengthening market intelligence wing in all markets along with the establishing of online marketing system through computerization and networking. Due to presence of seasonality in prices of cotton, there is need to generate greater awareness among the producers, so that they make rational decision on sale of their produce. In the wake of impact of international cotton prices on domestic cotton markets the suitable export policy measures might be put in place to minimize the international market price fluctuation on the domestic cotton prices

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Opinion of rural women regarding face masks to mitigate occupational health problems

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ABSTRACT : Women share abundant of responsibilities and perform a wide spectrum of duties in running the family, maintaining the household, care of domestic animals and attending various farm operations. Two types of face masks *i.e.* one pleated mask and one scarf mask were developed by Department of Textile and Apparel Designing, College of Home Science (COHS), CCS Haryana Gricultural University (HAU), Hissar, to mitigate health problems especially respiratory problems reported by rural women engaged in various household, animal husbandry and farm activities like cleaning and dusting, cooking, washing clothes and utensils, care of animals, fodder collection, cleaning of animal sheds,transplanting, weeding and harvesting etc. Porous cotton fabricof dark grey color was used to stitch these masks. Scarf facemask covers head along with mouth, nose and neck ofworkers while pleated beak face mask covers mouth, nose and neck of rural women. Four trainings of three days duration were organized in two villages of each districti.e. Gawar and Burrak of Hissar and Shahpur and Fazilpur of Sonipat district. These trainings were organized for twenty five rural women of each village to promote developed face masks.Opinion of rural women regarding developed face masks for different animal husbandry, household and farm activities with reference to functional, designing features and overall opinion was assessed on five-point scale. Majority of the rural women had high opinion regarding functional features of masks as they opined that these masks will be helpful in providing protection against dust and dirt (WMS 4.20) followed by the opinion that these are suitable for various household, animal husbandry and farm activities (WMS 4.10) and these will be helpful in increasing the work efficiency (WMS 3.94). They also had high opinion regarding designs of face masks as they opined that these designs are attractive (WMS 4.08) followed by the opinion that shape and size of the face masks is appropriate (WMS 4.02) and type and color of the fabric i.e. porous cotton fabric of dark grey color used to stitch face masks is suitable (WMS 4.00). Overall, rural women had high opinion regarding face masksfor different animal husbandry, household and farm activities as they opined that these face masks are functional (WMS 4.20) followed by the opinion that these are economical to make (WMS 4.08) and also modest as per village atmosphere (WMS 4.06)

Key words : Design, face masks, organic dust, pleated mask, scarf mask, work efficiency

Women constitute about one third of total labour force and undertake most of the labour intensive work that requires painstaking physical effort, patience and perseverance.They play a very significant role in family and community for brining decisive changes. They share abundant of responsibilities and perform a wide spectrum of duties in running the family, maintaining the household, care of domestic animals and attending various farm operations. In Haryana, rural women devote long working hours for home, animal husbandry and farm activities(Dahiya and Yadav, 2017). They perform a greater part of domestic work, took care of children and are intensely involved with the maintenance of household. Inlivestock management and production, women play multiple roles. Their activities vary widely ranging from care of animals to processing milk and livestock products. Most of theindoor livestock jobs like milking, feeding, cleaning, etc. are done by women in most of the rural families. They handle most of the critical jobs like feeding, milking, and care of newborn and administration of medicine also. They are well aware of each animal's behaviour and production characteristics. Women are knowledgeable about local feed resources and are able to identify beneficial fodder for feeding of dairy animals. They also know the feeding behaviour of each animal and prepare feed mixtures accordingly.

In tribal communities, much of the work with regard to animal management has to be looked after by women due to migration of males for work (Rani and Promila,2008)The major decision makers in agricultural activities are men even though women perform most of the farm activities. Harvesting of wheat crops ispredominantly performed by the women workforce in Haryana. This is a highly drudgerous activity for farmwomen in Haryana (Jyotsna*et al.*, 2014).

The occupational health and safety of rural women is one of the most neglected areas in household, animal husbandry and farm activities. While carrying out various household,animal husbandry and farm operations, they are exposed to a number of biological, physical and chemical factors harmful to their health like smoke, dirt and organic dust. Organic dust is extremely harmful due to the huge variety of components including ingredients of plants, animal proteins, bacteria, molds and their metabolites as mycotoxins (Wittczak *et al.*, 2012). Traditionally, to protect themselves from sun, smoke, husk, dust, etc., rural women in Haryana use *odhni*or *dupatta*to cover their head along with face, mouth, nose and neck during various household, animal husbandry and farm activities(Rani *et.al*,2015).

Keeping in view the various occupational health problems, especially the respiratory problems faced by rural women engaged in different types of household, animal husbandry and farm activities,two types of face masks i.e. one pleated mask and one scarf mask were developed by Department of Textile and Apparel Designing, COHS, CCS HAU, Hissar to mitigate these health problems. Porous cotton fabric of dark grey color, which could provide maximum protection against organic dust & dirt and harmful sun rays without hindering the breathing.

The Four trainings of three days duration were organized in two villages of each district *i. e.* Gawar and Burak of Hissar and Shahpur and

Fazilpur of Sonipat district. These trainings were organized for twenty five rural women of each village to promote developed face masks.As training can help the individuals to increase their knowledge and change the attitude (Anonymous, 2013). Opinion of rural women regarding developed face masks for different animal husbandry, household and farm activities with reference to designing, functional, features and overall opinion was assessed on five-point scale.

MATERIALS AND METHODS

Four trainings of three days duration were organized in two villages of each districts *i. e.* Gawar and Burrak ofHissar and Shahpur and Fazilpur of Sonipat district. These trainings were organized in collaboration with extension personnel for twenty five rural women of each village to promote developed two types of face masks *i.e.* one pleated mask and one scarf mask. Porous cotton fabric of dark grey color was used to stitch the masks.

Opinion of rural women regarding developed face masks for different animal husbandry household and farm activities with reference to functional, designing features and overall opinion was assessed on five-point scale *i.e.* highly agreed, agreed, somewhat agreed, least agreed and disagreed scoring 5,4,3,2 and 1using self-developed interview schedule. Weighted mean scores and average mean scores were categorized as high (5.00-3.34), medium (3.33-1.67) and low (1.66-1.00) opinion.

RESULTS AND DISCUSSION

As per technical report (2013-2014) published by CCSHAU, Hisar, the major occupational health problems encountered by rural women during various types of household, animal husbandry and farm activities arerespiratory problems along with running nose, sneezing, eye irritation/itching, headache, skin irritation/itching, and skin allergy/ailment etc. This was due to the reasons they did not wear appropriate protective clothing while performing these activities.Face masks were designed to create a barrier against breathing problems at work place *i.e.* household, animal husbandry and farm activities.The clothing creates an effective barrier between the health problems and the wearer(Nadiger and Samuel, 2004).

Four trainings of three days duration were organized for twenty five rural women each of Gawar and Burrak village of Hissar district

Table 1. Opinion of trainees regarding designs of face masks n=100

Sr. No.	Statements	WMS	Rank
1.	Shape and size of face masks is appropriate	4.02	II
2.	Dark grey color cotton fabric is suitable for face masks	4.00	III
3.	Designs of face masks are attractive	4.08	I
4.	These designs are easy to stitch especially by using paper patterns	3.46	IV
5.	These designs can also be made in other fabrics of dark colors	3.24	V

High (5.00-3.34), Medium (3.33-1.67) and Low (1.66-1.00) opinion and Shahpur and Fazilpur of Sonipat district, to promote developed face masksamongst target groups.Training is a vital tool to keep abreast of fast-changing technological developments and knowledge(Anita, 2006).The data regarding opinion of rural women for developed face masks for different animal husbandry, household and farm activities with reference to designing, functional features and overall opinion have been presented in Table-1,2 and 3.

The data furnished in the Table-1 depicts the opinion of rural women regarding various designing features of face masks. Majority of the trainees opined that the designs of face masks are attractive as this opinion got I[st]rank with WMS 4.80 followed by the opinion that shape and size of the protective clothing and accessories is appropriate, got II[nd]rank with WMS 4.02 and type and color of the fabric used to stitch protective clothing is suitable as porous cotton fabric of grey color provides resistance against dust &dirt and soiling, got III[rd] rank with WMS 4.00. They also thought that these designs are easy to stitch especially with paper patterns, ranked-IV with WMS 3.46 and these designs can also be made in other colors and fabrics, got V[th] rank with WMS 3.24.

Thus, majority of the rural women had high opinion regarding designs of face masks as they opined that these designs are attractive (WMS 4.08) followed by the opinion that shape and size of the face masks is appropriate (WMS 4.02) and type and color of the fabric i.e. porous cotton fabric of dark grey color used to stitch face masks is suitable (WMS 4.00).

Gandhi *et al.* (2012) also conducted a study on 20 farm workers to find out occupational health hazards & efficacy of protective masks in threshing operation. Respondents reported respiratory health problems, mainly due to heat and organic dust in the surroundings. All respondents reported irritation in eyes and

Table 2. Opinion of trainees regarding functional features of face masks n=100

Sr. No.	Statements	WMS	Rank
1.	The specific face masks will be helpful in providing protection against dust and dirt	4.20	I
2.	These are suitable for various household, animal husbandry and farm activities	4.10	II
3.	These will be helpful in increasing work efficiency	3.94	III
4.	These are comfortable to use	3.48	IV
5.	These are easy to wear and remove	3.40	V

High (5.00-3.34), Medium (3.33-1.67) and Low (1.66-1.00) opinion

Table 3. Overall opinion of trainees regarding face masks n=100

Sr. No.	Statements	WMS	Rank
1.	The specific face masks are functional	4.20	I
2.	The specific face masks are easy to maintain	3.60	IV
3.	These are economical to make	4.08	II
4.	These are as per latest trend	3.46	V
5.	These are modest	4.06	III

High (5.00-3.34), Medium (3.33-1.67) and Low (1.66-1.00) opinion throat followed by nose (85.0%) and ears (75.0%). Majority of the respondents (90.0%) always covered their nose and mouth by tying a piece of cloth during farm activities to protect themselves from the organic dust entering their respiratory track. Majority of the respondents used to wear clothes with full sleeves (85%) followed by drinking plenty of water (80%), while only 5 per cent respondents reported using eye glasses sometimes to protect their eyes.

The data pertaining to opinion of rural women regarding functional features of masks have been presented in Table-2. Majority of the trainees opined that these face masks will be helpful in providing protection against dust and dirt as this opinion got Istrank with WMS 4.20 followed by the opinion that these face masks are suitable for various household and animal husbandry activities, got IIndrank with WMS 4.10 and these will be helpful in increasing the work efficiency, got IIIrdrank with WMS 3.94. The rural women also thought that these face masks are comfortable to use, got IVth rank with WMS 3.48 and these are easy to use, ranked-V with WMS 3.40.

Thus, majority of the rural women had high opinion regarding functional features of face masks as they opined that these face masks will be helpful in providing protection against dust and dirt (WMS 4.20) followed by the opinion that these are suitable for various household and animal husbandry activities (WMS 4.10) and these will be helpful in increasing the work efficiency (WMS 3.94).

Dahiya and Yadav (2017) conducted on farm trials of protective face masks of cotton fabric for farmers and found these masks were highly suitable in providing protection against dust, dirt and sun during wheat harvesting/ threshing activities, thereby increasing the efficiency of work. Moreover, they were also comfortable and easy to use.

The data pertaining to overall opinion of rural women regarding face masks have been presented in Table-3. Majority of the trainees opined that these face masks are functional as this opinion got Istrank with WMS 4.20 followed by the opinion that these are economical to make, got IIndrank with WMS 4.08 and these are modest as per village atmosphere, got IIIrdrank with WMS 4.06. The respondents also thought that these are easy to maintain, ranked-IV with WMS 3.60 and these are also as per latest trend, got Vth rank with WMS 3.46.Thus, majority of the rural women had overall high opinion regarding protective clothing and accessories as they opined that these protective clothing and accessories are functional (WMS 4.20) followed by the opinion that these are economical to make (WMS 4.08) and these are modest as per village atmosphere (WMS 4.06)

CONCLUSION

Rural women are exposed to several health problems during household, livestock and agricultural operations.Two types of face masks i.e. one pleated mask and one scarf mask were developed by Department of Textile and Apparel Designing, COHS, CCS HAU, Hissar were promoted in two districts of Haryana and opinion of rural women was assessedregarding face masks for different animal husbandry and household activities with reference to designing,functional, features and overall opinion.Rural women had high opinion about developed face masksfor different animal husbandry, household and farm activities with reference to designig, functional features and overall opinion with average mean scores 3.76,3.82 and 3.88.

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Effect of methods of gap filling on the productivity of hybrid *Bt* cotton

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ABSTRACT : Cotton (*Gossypium hirsutum* L.) is one of the most important fibre and cash crop in India and known as *"King of Fibers"* and *"White gold"* plays a pivotal role in the rural, national and international economy. The northern cotton zone is mainly spread in Haryana, Punjab and Rajasthan states of India, which is 100 per cent irrigated. Highly vulnerable and extreme climatic conditions of North India, *i.e.* high temperature, rains and hot winds during sowing and seeding stage in May and June often results in the poor/negligible plant stand in some fields which require re-sowing, hence technology to maintain proper plant stand of hybrid *Bt* cotton needs to be evolved. A field experiment was therefore conducted at the research farm of ICAR-CICR, Regional Station, Sirsa, Haryana, India on a Gangatic alluvial soil during *kharif* season of 2017-2018 to determine the effects of methods of gap filling [*i.e.* (i) Gap filling using inherent moisture; (ii) Gap filling after hand irrigation at the point of seeding / gap; (iii) Gap filling after first irrigation; and (iv) control with normal plant population at initial actual sowing] on productivity of hybrid Bt cotton. The field experiment was conducted in randomised complete block design. The sowing was done with hand by dibbling method and a heavy pre-sowing irrigation was applied before initial sowing. Among the methods of gap filling, growth and yield attributes as well as seed cotton yield (of gap filled plants or otherwise) was significantly higher under control treatment *i.e.* control with normal plant population at initial actual sowing (122.0 g/plant) and there was significant reduction in all parameters under all other treatments. Second best treatment was gap filling using inherent moisture with respect to all parameters including seed cotton yield (59.0 g/plant) and was significantly superior over gap filling after hand irrigation at the point of seeding / gap with seed cotton yield of 23.0 g/plant. Least seed cotton yield (11.4 g/plant) and other parameters were recorded with gap filling after first irrigation. Thus, gap filling using inherent moisture can be a better option for gap filling amongst the tested methods of gap filling if the plant stand is poor with the initial sowing.

Key words : Gap filling, hybrid *Bt* cotton, seed cotton yield, yield attributes.

Cotton (*Gossypium hirsutum* L.), is one of the most ancient and important commercial crop next to food grains. Due to its importance in agriculture as well as in industrial economy, it is also known as *"King of Fibers"* and *"White gold"*. Cotton plays a pivotal role in the rural, national and international economy (Udikeri and Shashidhara, 2017). Cultivation of *Bt* cotton hybrids has resulted in higher productivity at reduced cost of production and environmental pollution. The northern cotton zone is mainly spread in Haryana, Punjab and Rajasthan states of India, which is 100 per cent irrigated. The actual yield level of timely sown *Bt* cotton in north-west part of India is low compared to the potential productivity due to poor germination and high rate of seedlings mortality after germination due to abnormally high soil temperature (ranging from 48 to 52!), resulting in poor plant stand. Highly vulnerable and extreme climatic conditions of north India, *i.e.* high temperature, rains and hot winds during sowing and seeding stage in May and June often results in the poor/negligible plant stand in some fields which require re-sowing (Rajpoot *et al.,* 2016). In any crop, especially in cotton a full crop stand / good crop stand has always been considered one of the most important factors in obtaining a good yield. A proper technique for gap filling may be a way out to ensure optimum plant stand to obtain good yield. In cotton, there is ample scope to obtain good yield by maintaining proper plant stand through gap filling owing to wider spacing. Hence technology to maintain proper plant stand of hybrid *Bt* cotton needs to be evolved.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of ICAR-CICR, Regional Station, Sirsa, Haryana, India during *kharif* season of 2017-18 to determine the effects of methods of gap filling [*i.e.* (i) Gap filling using inherent moisture; (ii) Gap filling after hand irrigation at the point of seeding / gap; (iii) Gap filling after first irrigation; and (iv) control with normal plant population at initial actual sowing] on productivity of hybrid *Bt* cotton. The field experiment was conducted in randomised complete block design. The soil at the experimental field was sandy loam (Gangatic alluvium) having 107 kg/ha alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 11.6 kg/ha available phosphorus (P) (Olsen *et al.*, 1954), 218 kg/ha ammonium acetate-exchangeable potassium (K) (Hanway and Heidel, 1952), 0.32 g/kg organic carbon (OC) (Walkley and Black, 1934). The pH of soil was 8.2 at a soil and water ratio of 1:2.5 (weight:volume) and electrical conductivity (EC) was 0.20 dS m^{-1} (Prasad *et al.*, 2006). The sowing was done with hand by dibbling method and a heavy pre-sowing irrigation was applied before initial sowing. Row-to-row spacing of 67.5 cm and plant-to-plant spacing of 60 cm was maintained at initial sowing. Two seeds of Bt cotton hybrid "RCH 776 (BG II)" were dibbled per hill on 20th April, 2017 during the initial sowing. Gap filling was done on 01st May; 07th May; 26th May, 2017, treatment wise [for (i), (ii) and (iii) treatments] respectively and initial actual sowing was done on 20th April, 2017 [for (iv) treatment]. Treatments were imposed on the natural gaps which were observed after the initial sowing. Initial plant stand (before execution of gap filling treatments) ranged from 57.5 to 76.4 per cent across the treatments. Randomized gaps ranging from 23.6 to 42.5 per cent of the stand were filled and left open for comparison, the filling being done 10, 17 and 26 days after initial planting. Recommended dose of nitrogen (150 kg

N/ha) as urea was applied in 2 equal splits-first at thining and remaining half at the appearance of the first flower. The recommended dose of phosphorus (30 kg P_2O_5/ha) as single superphosphate and potassium (25 kg K_2O/ha) as muriate of potash was applied at sowing. Need based plant protection measures were taken as per local recommended package of practices. A total number of four irrigations were applied as and when required. Picking was done thrice at full boll burst stage manually. Observations on growth, yield attributes and seed cotton yield were made on 20 selected tagged plants (of gap filled plants or otherwise) per plot. Seed cotton was cleaned and weighed from each plant (of gap filled plants or otherwise) for expressing seed cotton yield g/plant. All the replicated data obtained from this study were statistically analyzed by the *F*-test as per the procedure given by Gomez and Gomez (1984). Least significant difference (LSD) values at $P = 0.05$ were used to determine the significance of differences between treatment means.

RESULTS AND DISCUSSION

Amongst the methods of gap filling, plant height (Fig. 1) and yield attributes like number of monopods; number of sympods; number of bolls as well as seed cotton yield (of gap filled plants or otherwise) was significantly higher under control treatment *i.e.* control with normal plant population at initial actual sowing and there was significant reduction in all parameters under all other treatments [Fig. 2 (A, B, C and D)]. Second best treatment was gap filling using inherent moisture with respect to all parameters including seed cotton yield (59.0 g/plant) and was significantly superior over gap filling after hand irrigation at the point of seeding / gap with seed cotton yield of 23.0 g/plant. Least seed cotton yield (11.4 g/plant) and other parameters were recorded with gap filling after first irrigation [Fig. 1 and 2 (A, B, C and D)].

Significantly higher values of all the observed parameters under control treatment *i.e.*

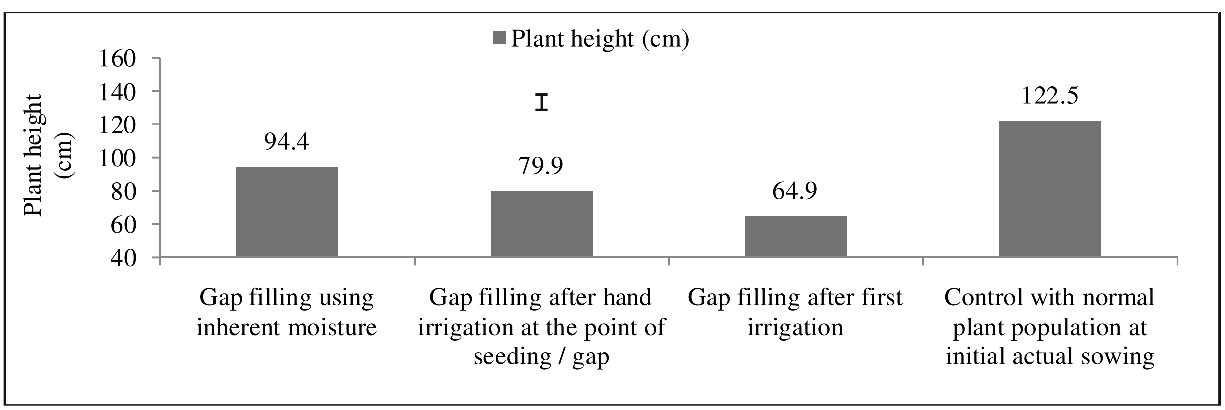

Fig. 1. Effect of methods of gap filling on the plant height of hybrid Bt cotton. The vertical bars represent least significant difference values at $P = 0.05$.

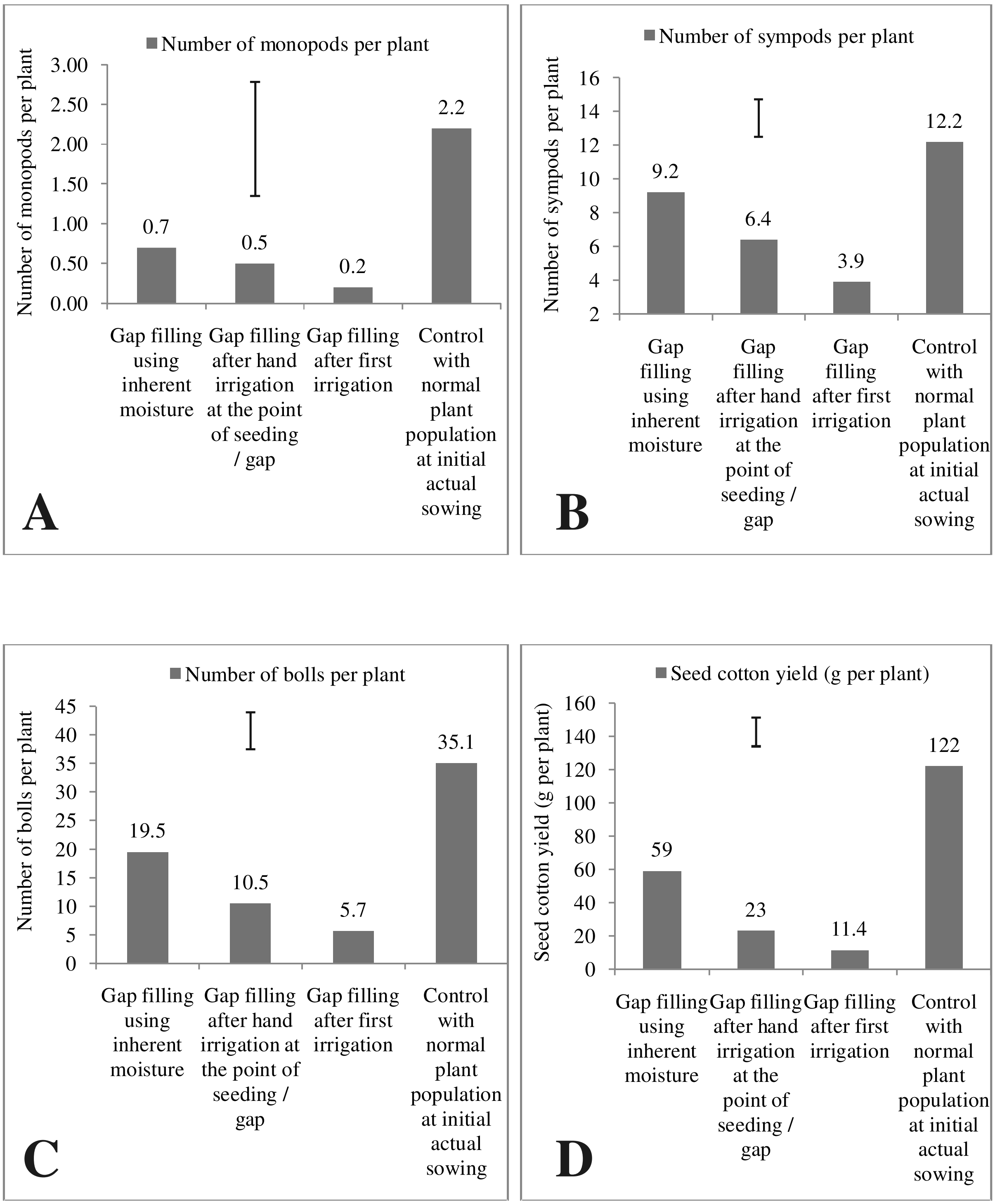

Fig. 2 (A, B, C & D) Effect of methods of gap filling on the number of monopods (A); number of sympods (B); number of bolls (C); and seed cotton yield (D) per plant of hybrid Bt cotton. The vertical bars represent least significant difference values at *P* = 0.05.

control with normal plant population at initial actual sowing may be due to early establishment (planted early at the initial sowing) and lesser competition in the sparse plant stand resulting in better growth and development. In the treatment 'gap filling using inherent moisture' the plants got early establishment as compared to other treatments (excluding control as gap filling was done 10 days after initial planting) resulting in better growth and development. Gap filling using inherent moisture (stored in soil with seed bed preparation after pre-sowing irrigation) can be effectively utilised for gap filling within a few days (4-6 days or so) after initial sowing, if gaps appears in the field. With the passage of time (2-3 days or so) the soil surface gets dried due to dry and hot winds. High atmospheric and soil temperatures (ranging from 48 to 52!), and hot and dry winds during sowing and seedling stage in April to June often results in the poor/negligible plant stand in some fields which require re-sowing (Rajpoot *et al.,* 2016). This is because hot and dry winds quickly evaporate the soil moisture resulting in dry (surface) soil. The sowing, emergence and establishment of plants with gap filling 'gap filling after hand irrigation at the point of seeding / gap' and 'gap filling after first irrigation' was delayed because of late sowing (the gap filling being done 17 and 26 days after initial planting).

Also the soil might have got hardened after irrigation in these two treatments, which adversely affected the growth and development of the plants. The plants grown by gap filling either with 'gap filling after hand irrigation at the point of seeding / gap' or 'gap filling after first irrigation' did not lead to any increase in yield.

CONCLUSION

Thus, gap filling using inherent moisture can be a better option for gap filling amongst the tested methods of gap filling if the plant stand is poor with the initial sowing.

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CROP PROTECTION AND BIOSAFETY

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Radiation technology (SIT) for management of cotton pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera : Gelechiidae) as an integral component of cotton IPM

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ABSTRACT : Radiobiological investigations were carried out to select an appropriate ionizing dose to be employed for sterile insect technique in pink bollworm *Pectinophora gossypiella* (Saunders). The three day old pupae were irradiated with 50, 100, 150 and 200 Gy of gamma radiation, after adult emergence moths were crossed with different combinations like NB&× N@& (Control), TB&× N@&, NB&× T@& and TB&× T@& in oviposition cage. The fecundity was significantly decreased with increasing irradiation dose and treated males when mated with normal females laid fewer eggs than other two crosses. The decrease in per cent egg hatch and increase in per cent sterility induced by gamma radiation were found to be positively correlated with the dose level in all the three crosses than control. Complete sterility was achieved at 200Gy, when three day old pupae treated with higher gamma radiation dose. At 150Gy, the per cent corrected sterility was 72.42 to 92.48 per cent in all the three crosses.

Key words: Irradiation, *pectinophora gossypiella,* sterile insect technique (SIT), sterility

Cotton production has remained stagnant over the years owing to many biotic and abiotic constraints making it uneconomical even world over so for. Among the biotic problems, insect pests are major in India.

Recently cotton pest scenario has witnessed considerable changes in southern part of India and also in the cotton growing areas of Northern Karnataka. The outbreak of Pink bollworm (PBW) *Pectinophora gossypiella* cause major threat to cotton production in this area. Pink bollworm has progressively increased its activity and developed resistance to cry proteins in *Bt* cotton. Steady increase in its incidence in the later stage of the crop reducing the lint yield and leading to low quality lint. Pink bollworm incidence goes unnoticed to the farmers since young larvae enter the cotton boll in the developing stage and remains inside by feeding on seeds. Its damage will be seen only when bad opened bolls with damaged seeds found at harvesting stage. Non removal of stubbles and discarded damaged bolls left over in the cotton fields for larger period narrowed the interval between two seasons and it might have supported pest survival in off season and formed an important link in the carryover of the pest.

Higher level of resistance particularly against insecticides and *Bt* proteins coupled with collapse of natural enemies population warrants alternative control measures for cotton and unfortunately, none of the IPM modules had a sound, Under such circumstances, the radiation technology (Sterile insect technique) which involves mass rearing, sterilising and releasing large numbers of insects to reduce or eliminate subsequent generations of feral populations of the target pest is the better option. Radiation mediated sterile insect technique (SIT) is an environmentally innocuous and target-specific control tactic in suppressing the pest population and

Pink bollworm has exhibited typical characteristic lepidopteron response to gamma radiation. The purpose of the present study was to provide much needed information on reproductive behaviour, developmental profile and survival of F_1 progeny of *P. gossypiella* at different gamma radiation doses.

MATERIALS AND METHODS

For detailed radiobiological studies of PBW**,** larvae of the pink bollworm were collected from infested cotton bolls, individual larva from infested bolls were then transformed to artificial diet in bioassay trays covered with perforated cap and kept in growth chamber by maintaining the temperature at 27±0.5°C, relative humidity of 60±10% and photoperiod of 14L:10D until pupation (Dharajothi *et al.*, 2010).

Sex differentiation of the pink bollworm was done both in the larval and pupal stage as mentioned by Dharajothi *et al.*, (2010) for pairing adult moths. After adult emergence, they were collected and released in oviposition jars of 45 x 30 x 30 (l x b x h) cm size containing cotton twigs having terminal leaves and squares inserted in a small plastic container with 10 per cent sucrose solution as adult food and also for egg laying. The bottom of the twigs was immersed in water to retain the turgidity of the tissue. Cotton twigs were changed once in two days in the oviposition jars and then transferred to a transparent plastic containers covered with black cloth and tightly fastened with a rubber band for egg hatching. The first instar larvae were transferred individually into rearing trays containing semi-synthetic diet and covered with perforated cap. The second instar larvae were later transferred individually to plastic vial with perforations on the cap for aeration. Fresh diet was supplemented whenever necessary until pupation. This culture was utilized for further investigations of radiobiological studies under the laboratory conditions.

Basic ingredients of the diet consist of cotton seed flour, *Kabuli* gram flour, carbohydrate, protein, fat sources, multivitamin, antimicrobial agent and agar as thickening agent.

In the present study, the most commonly used radiation source was cobalt-60 (CO^{60}). Gamma Chamber-5000 having maximum capacity of dose rate at 9kGy/hr. For irradiation, ten pairs of three day old pupae were exposed to different doses of gamma radiation *viz.*, 0, 50, 100, 150 and 200 Gy. After irradiation pupa were kept for adult emergence then paired with different mating combinations *viz.*, N@& × NB& (Control), N@& × TB&, T@& × NB& and T@& × TB& to study the reproductive behaviour. Four replicates of each combination were made, each replicate containing ten pairs of male and female. These mating combination of moths were released into the oviposition cage kept in the growth chamber for mating and oviposition. The ovipositional behaviour was recorded in terms of total number of eggs laid per female. The per cent egg hatch was assessed by recording the number of eggs hatched out of total number of eggs laid in each replication. Corrected sterility and Control of Reproduction were computed based on formula mentioned below (Seth and Reynolds 1993).

$$\textbf{Corrected sterility } (\%) = \frac{\text{Fertility in control} - \text{Fertility in treated}}{\text{Fertility in control}} \times 100$$

$$\textbf{Control of reproduction } (\%) = \frac{\text{Viablity in control} - \text{Viablity in treated}}{\text{Viablity in control}} \times 100$$

RESULTS AND DISCUSSION

The mean number of eggs laid by normal female treated with male obtained from irradiated pupa was significantly decreased from 30.22 to 0.61eggs in a dose range of 50 to 200 Gy against to control where it was 80.14 eggs/ female. As the irradiation dose increased per cent egg hatch was decreased significantly from 82.25 to nil at 200 Gy (Table 1). Radiation induced reduction in fertility led to 24.30-100 and 69.94-100 per cent sterility and per cent control of reproduction at dose range of 50 and 200 Gy respectively.

The effect of 50-200 Gy gamma dose range was significantly affected on the reproductive behaviour. The fecundity was significantly reduced in treated female mated

Table 1. Effect of gamma radiation doses on reproductive behaviour of *P. gossypiella* pupae as normal @&× treated B&.

Irradiation dose(Gy)	Eggs/female	Egg hatching (%)	Corrected sterility (%)	Control of reproduction(%)
0	80.14(8.73)[a #]	82.25 (64.52)[a**]	0.00(0.00)[e**]	0.00(0.00)[e**]
50	30.22(5.83)[b]	63.54(51.72)[b]	25.14(29.45)[d]	72.15(57.42)[d]
100	18.45(4.80)[c]	39.42(37.95)[c]	56.63(48.13)[c]	90.43(70.93)[c]
150	12.58(3.45)[d]	25.22(29.13)[d]	78.22(58.45)[b]	97.34(78.68)[b]
200	0.61(0.64)[e]	0.00(0.00)[e]	100 (90.00)[a]	100 (90.00)[a]
F- value	F= 354.58* df= 4, 15	F= 383.54* df= 4, 15	F= 422.56* df= 4, 15	F= 1.38* df= 4, 15

[#] Figures in the parentheses are $\sqrt{X+0.5}$ transformed values; ** Figures in parentheses are arc sine transformed values;

* indicates significant at Pd” 0.01 level and transformed data followed by same letter within a column are not significantly different at Pd” 0.01 level.

with normal male ranging from 18.43 to 0.45 eggs per female at increasing irradiation doses of 50-200 Gy. The per cent egg hatch was significantly highest in control *i.e.* 78.42 per cent, which drastically reduced to 13.44 per cent at 150 Gy dose and it was nil when exposed to 200 Gy (Table 2). The per cent sterility induced by gamma irradiation was found to be positively correlated with the dose level, corrected sterility and control of reproduction was found to be 43.52 to 100 and 90.14 to100 per cent in a dose range of 50-200 Gy, respectively.

Treated female mated with treated male had inhibitive effect on all reproductive parameters of pink bollworm compared to other mating combinations. Mean number of eggs laid by treated female mated with treated male was diminished from 84.43 (control) to 5.84, 3.15 and 0.74 at 50, 100 and 150 Gy, respectively. The higher dose 200 Gy completely inhibited per cent egg hatch, thus per cent egg hatch greatly reduced from 84.52 (control) to 6.11 at 150 Gy (Table 3). Radiation induced reduction in fertility led to 46.23 to100 per cent and 97.81 to 100 per cent corrected sterility and control of reproduction in a dose range of 50-200 Gy, respectively.(Table 3).

Over all our results demonstrated that three day old pupae of *P. gossypiella* treated with gamma radiation in different doses were effectively induced the sterility at different levels. Complete sterility was achieved by treating pupae of three day old at 200 Gy in all mating combinations (N@& × TB&, T@& × NB& and T@& × TB&).

In the present study, fertility and hatchability of the eggs was decreased with an increase in irradiation dose. This is a normal radiobiological reaction because radiation interferes with cell division in the reproductive system of the females during its initial stage of development, causing complete atrophy of the ovaries and females laid no eggs when exposed to higher doses. Similar studies were made by Walder and Calkines (1993) irradiated the *Plodia interpunctella* pupae at with 15, 20, 25, 30, 50 and 70 Gy of gamma radiation (Co^{60}). The radiation effects on sterility and behaviour of males and females of the pest were established.

Our results were also agree with Abdel-

Table 2. Effect of gamma radiation doses on reproductive behaviour of *P. gossypiella* pupae as treated @&× normal B&.

Irradiation dose(Gy)	Eggs/female	Egg hatching (%)	Corrected sterility (%)	Control of reproduction(%)
0	88.15(9.32)[a #]	78.42 (62.43)[a]	0.00(0.00)[e]	0.00(0.00)[e]
50	18.43(4.15)[b]	46.34(43.15)[b]	43.52(40.54)[d]	88.28(69.99)[d]
100	13.44(4.11)[c]	26.42(30.14)[c]	70.42(55.94)[c]	96.01(78.53)[c]
150	3.12(1.58)[d]	13.44(19.12)[d]	89.18(69.13)[b]	99.56(86.30)[b]
200	0.45(0.57)[e]	0.00(0.00)[e]	100 (90.00)[a]	100 (90.00)[a]
F- value	F= 66.13*	F= 208.14*	F= 231.54*	F= 6.51*
	v	df = 4, 15	df = 4, 15	df = 4, 15

[#] Figures in the parentheses are transformed values; ** Figures in parentheses are arc sine transformed values; * indicates significant at Pd" 0.01 level and transformed data followed by same letter within a column are not significantly different at Pd" 0.01 level.

Baky (1986), who studied the effect of gamma irradiation on *Ephestia kuehniella* pupae. The exposure of the pupae to radiation caused a reduction in fecundity and egg hatchability. It means that reduction in fecundity and egg fertility were dose dependent, these results also agree with Ibrahim and El-Naggar (2001) on *Spodoptera littoralis* (Boisd.). They found that fecundity of untreated females mated with treated males declined gradually with increase in the radiation doses. Fertility of treated males declined almost linearly to reach zero per cent at 400 Gy approximately.

Our results are in agreement with Hilmy *et al.*, (1984), where they found that gamma radiation positively affected the developmental periods of *Spodoptera littoralis*, where irradiation dose increased the developmental period of egg, larva and pupa. Hasaballa *et al.,* (1985) also noticed that, when the rice moth, *Corcyra cephalonica* was irradiated as pupae, the irradiation increased the developmental periods of the F_1 progeny.

Similarly, Sallam (1991), has the same findings when he exposed fully-grown male pupae of the noctuid, *Spodoptera littoralis* to substerilizing doses of gamma-radiation, where the average of developmental periods were positively affected by the irradiation doses. Makee and Saour (2003) assumed that unbalanced hormonal system led to prolonged developmental time in the F_1 larvae of the potato tuber moth (PTM), *Phthorimaea operculella* Zeller.

Longevity of F_1 adults of pink bollworm was not significantly different from normal adult moths, but F_1 adults from 150 Gy irradiated parents lived significantly shorter than untreated adults. The present results are also in line with those reported by Hollis *et al.,* (1967), Henneberry and Clayton (1988), Qureshi *et al.*, (1993) and Prapon *et al.* (2000) on F_1 progeny of pink bollworm, *Pectinophora gosspiella.* All these changes on the reproduction of F_1 progeny must be related to altered genetic information inherited from the treated male parent

Similarly, Abass *et al.*, (2017) reported that the susceptibility of males *Spodoptera littoralis* to different doses of gamma irradiation based on LD_{25}, LD_{50}, LD_{75} and LD_{95}were 18, 53, 157 and 416 Gy, respectively. The results showed

Table 3. Effect of gamma radiation doses on reproductive behaviour of *P. gossypiella* pupae as treated@&× treated B&.

Irradiation dose(Gy)	Eggs/female	Egg hatching (%)	Corrected sterility (%)	Control of reproduction(%)
0	84.43(8.94)[a]	84.26(64.44)[a]	0.00(0.00)[e]	0.00(0.00)[e]
50	5.84(3.12)b	43.46(40.75)[b]	46.23(43.23)[d]	97.81(79.86)[d]
100	3.15(1.72)[c]	27.35(21.14)[c]	72.56(57.18)[c]	99.15(84.22)[c]
150	0.74(0.78)[d]	8.53(14.56)[d]	92.48(74.58)[b]	99.74(88.31)[b]
200	0.00(0.00)[e]	0.00(0.00)[e]	100 (90.00)[a]	100(90.00)[a]
F- value	F= 1.82*	F= 126.17*	F= 194.32*	F= 8.72*
	df = 4, 15	df = 4, 15	df = 4, 15	df = 4, 15

[#] Figures in the parentheses are transformed values; ** Figures in parentheses are arc sine transformed values; * indicates significant at Pd" 0.01 level and transformed data followed by same letter within a column are not significantly different at P d" 0.01 level.

that fecundity of irradiated males crossed with non-irradiated females was decreased by increasing irradiation dose. The decrease in egg hatchability per cent and increase in sterility per cent induced by gamma radiation were found to be posi-tively correlated with the dose level.

Suubiyakato *et al*., (1998) reported that sterilized moths of *Helicoverpaarmigera*by irradiating the adult stage. The dosages were 1, 3, 5, 7, 9, 11, 13, and 15 krad. The resultsshowed that sub sterile dosage (LD_{50}) for males was 0.94 kradand 7.02 krad for females. The sterile dosage (LD_{95}) for maleswas 10.85 krad and 14.35 krad for females.

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Biorational management of *Pectinophora gossypiella* in *Bt* cotton

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ABSTRACT : The present investigation entitled was carried out during kharif of 2018-19 on, the research farm of Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The field experiment was laid out in Randomized Block Design with nine treatments and three replications. The results revealed that minimum green fruiting bodies damaged was recorded in treatment T_6 *i.e.* 0.68 per cent where weekly destruction of rosette flower along with five releases of trichocards @ 3 cards/ac alternated with four sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE were carried out whereas, maximum 2.01 per cent was recorded in untreated control. Same trend was observed in case of green boll damaged where minimum green boll damaged recorded due to pink bollworm was 9.58 per cent and maximum 32.92 per cent was observed in control. Overall minimum pink bollworm damage was recorded in treatment T_6 *i.e.* 10.83 per cent and maximum 52.41 per cent was recorded in untreated control at the time of harvest. Maximum seed cotton yield (12.53 q/ha) was also recorded in treatment T_6 whereas minimum 6.36 q/ha was recorded in control T_9. From the overall data it was concluded that weekly destruction of rosette flower + five releases of trichocards @ 3 cards/ac alternated with four sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE provided maximum protection from pink bollworm damage in Bt cotton. As the number of releases and sprays decreases pink bollworm damage increases. However, on the basis of incremental cost benefit ratio weekly destruction of rosette flowers + five releases of trichocards @ 3 cards/ac alternated with four sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE were found economical.

Key words : Azadirachtin, *Beauveria bassiana,* pink bollworm, trichocards.

Cotton the **"King of Fibres"** or **"White Gold"** is one of the most important crop producing natural fibre which has been under commercial cultivation for domestic consumption and export needs of about 111 countries in the world. Major constraint in attaining high production of seed cotton is the damage inflicted by insect pests. Insect pest problems in agriculture have shown a considerable shift during first decade of twenty-first century due to ecosystem and technological changes. Among the insect pests of economic importance, now a days pink bollworm *Pectinophora gossypiella* (Saunders), is the most important and have been reported to cause serious quantitative and qualitative losses in Bt cotton crop. *P. gossypiella* is one of the most serious pests of cotton worldwide causing losses in both yield and quality of cotton. It is distributed in almost all cotton growing states of the country and has caused millions of the rupees of damage during last 3-4 years.

MATERIALS AND METHODS

The present investigation was carried out at research farm of Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *Kharif* 2018-2019. Field experiment was laid out in Randomized Block Design with nine treatments replicated thrice. The treatment details are as follows:

Periodical observations were undertaken to record fruiting bodies damage by pink bollworm at weekly interval started from square formation. The observations of green bolls damaged due to pink bollworm were recorded from 90 days after emergence (DAE) up to 160 DAE at an interval of 10 days. Randomly 20 matured green bolls were plucked from each plot and these bolls were dissected and observed for pink bollworm damage. The data thus, obtained was expressed in terms of per cent green boll damage and per cent loculi damage. For recording open boll damage and loculi damage due to pink bollworm, all open bolls randomly selected from five plants from each net plot were assessed at final picking. From this data the per cent open boll damage and loculi damage at harvest was worked out.

Treatment No	Treatment details
T_1	Weekly destruction of rosette flowers starting at 50 DAE + 3 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE
T_2	Weekly destruction of rosette flowers + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 10 days interval starting at 50 DAE
T_3	Weekly destruction of rosette flowers + 5 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE
T_4	Weekly destruction of rosette flowers + 7 releases of trichocards @ 3 cards/ac at 10 days interval starting at 50 DAE
T_5	Weekly destruction of rosette flowers + 9 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE
T_6	Weekly destruction of rosette flowers + 5 releases of trichocards @ 3 cards/acre alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE
T_7	Weekly destruction of rosette flowers starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 10 days interval starting at 50 DAE
T_8	Weekly destruction of rosette flowers starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/ac at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 80 DAE
T_9	Control

Table 1: Effects of different treatments on per cent green fruiting bodies damage by pink bollworm :

Tr. No.	TREATMENTS	Green fruiting bodies damage (%) 45 DAE	52 DAE	59 DAE	66 DAE	73 DAE	80 DAE	87 DAE	94 DAE	101 DAE	108 DAE	115 DAE	122 DAE	C MEAN
T1	Weekly destruction of rosette flower starting at 50 DAE + 3 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE.	1.63 (1.28)*	1.73 (1.31)*	1.49 (1.22)*	1.96 (1.39)*	1.98 (1.40)*	2.42 (1.55)*	2.63 (1.62)*	1.01 (1.01)*	0.60 (0.77)*	0.00 (0.00)*	0.00 (0.00)*	0.00 (0.00)*	1.72 (1.28)*
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 liters of water at 10 days interval starting at 50 DAE	1.68 (1.30)	1.86 (1.36)	1.98 (1.41)	2.11 (1.45)	2.17 (1.47)	2.26 (1.50)	2.48 (1.57)	1.05 (1.02)	0.56 (0.75)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.79 (1.31)
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	1.40 (1.18)	1.39 (1.17)	1.34 (1.15)	1.61 (1.26)	1.58 (1.25)	1.49 (1.21)	1.63 (1.27)	0.89 (0.94)	0.45 (0.67)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.31 (1.12)
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/acre at 10 days interval starting at 50 DAE	1.34 (1.15)	1.33 (1.15)	1.01 (1.00)	1.39 (1.17)	1.52 (1.23)	1.44 (1.19)	1.22 (1.08)	0.71 (0.84)	0.40 (0.63)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.15 (1.05)
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	1.19 (1.09)	1.12 (1.06)	1.00 (0.98)	1.24 (1.09)	1.14 (1.07)	1.27 (1.12)	1.13 (1.05)	0.69 (0.82)	0.33 (0.57)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.01 (0.98)
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre alternated with 4 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE	0.69 (0.68)	1.06 (1.02)	0.75 (0.87)	0.57 (0.76)	0.73 (0.84)	0.57 (0.61)	1.03 (1.01)	0.65 (0.80)	0.07 (0.15)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.68 (0.75)
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	1.55 (1.24)	1.45 (1.20)	1.42 (1.19)	1.69 (1.29)	1.66 (1.27)	1.84 (1.34)	2.19 (1.48)	0.89 (0.94)	0.48 (0.69)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.46 (1.18)
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/acre at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	1.60 (1.26)	1.58 (1.24)	1.47 (1.21)	1.76 (1.32)	1.93 (1.39)	2.19 (1.48)	2.38 (1.54)	0.94 (0.97)	0.51 (0.71)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.60 (1.24)
T9	Control	1.73 (1.32)	2.11 (1.45)	2.20 (1.48)	2.49 (1.58)	2.50 (1.58)	2.59 (1.61)	2.75 (1.66)	1.08 (1.04)	0.66 (0.81)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.01 (1.39)
	F test	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	-	-	-	Sig
	SE (m) ±	0.107	0.083	0.081	0.093	0.085	0.099	0.087	0.056	0.048	0	0	0	0.062
	CD at5%	0.32	0.25	0.24	0.29	0.25	0.29	0.26	0.17	0.14	0	0	0	0.18
	CV %	15.89	11.80	12.03	12.79	11.46	13.31	11.07	10.36	12.94	0	0	0	9.30

Table 2: Effects of different treatments on per cent green boll damage by pink bollworm :

		Green boll damage (%)								
Tr. No.	TREATMENTS	90 DAE	100 DAE	110 DAE	120 DAE	130 DAE	140 DAE	150 DAE	160 DAE	C MEAN
T1	Weekly destruction of rosette flower starting at 50 DAE + 3 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE.	6.67 (2.11)*	10.00 (3.16)*	23.33 (28.78)**	26.67 (31.00)**	30.00 (33.00)**	33.33 (35.22)**	40.00 (39.15)**	46.67 (43.08)**	27.08 (27.99)
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 liters of water at 10 days interval starting at 50 DAE	10.00 (3.16)	10.00 (3.16)	26.67 (31.00)	30.00 (33.00)	33.33 (35.22)	36.67 (37.22)	43.33 (41.15)	50.00 (45.00)	30.00 (29.39)
T3	Weekly destruction of rosette flowers + 5 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	6.67 (2.11)	6.67 (2.11)	16.67 (23.86)	16.67 (23.86)	20.22 (26.07)	23.33 (28.29)	33.33 (35.22)	33.33 (35.22)	19.58 (23.04)
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/acre at 10 days interval starting at 50 DAE	3.33 (1.05)	6.67 (2.11)	13.33 (21.14)	13.33 (21.14)	16.67 (23.86)	20.00 (26.57)	26.67 (30.79)	30.00 (33.21)	16.25 (20.88)
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	3.33 (1.05)	3.33 (1.05)	10.00 (18.43)	10.00 (15.00)	13.33 (21.14)	16.67 (23.86)	23.33 (28.78)	26.67 (31.00)	13.33 (18.31)
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre alternated with 4 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE	0.00 (0.00)	3.33 (1.05)	3.33 (6.14)	6.67 (12.29)	10.00 (18.43)	13.33 (21.14)	20.00 (26.07)	20.00 (26.07)	9.58 (14.33)
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	6.67 (2.11)	10.00 (3.16)	20.00 (26.57)	20.00 (26.07)	23.33 (28.78)	26.67 (31.00)	40.00 (39.15)	36.67 (37.14)	22.92 (25.14)
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/acre at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	6.67 (2.11)	10.00 (3.16)	23.33 (28.78)	23.33 (28.78)	26.67 (31.00)	30.00 (33.00)	40.00 (39.15)	40.00 (39.23)	25.00 (26.46)
T9	Control	10.00 (3.16)	13.33 (3.60)	30.00 (33.00)	33.33 (35.22)	36.67 (37.22)	40.00 (39.15)	46.67 (43.08)	50.00 (45.00)	32.92 (30.23)
	F test	NS	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE(m) ±	0.878	0.715	2.650	2.839	2.784	2.421	3.528	2.845	2.333
	CD at 5 %	2.63	2.14	7.94	8.51	8.34	7.25	9.76	8.52	6.89
	CV %	81.19	49.38	18.97	19.55	17.03	13.70	15.75	13.24	28.60

Table 3: Effects of different treatments on per cent loculi damage by pink bollworm :

		Loculi damage (%)								
Tr. No.	**TREATMENTS**	**90 DAE**	**100 DAE**	**110 DAE**	**120 DAE**	**130 DAE**	**140 DAE**	**150 DAE**	**160 DAE**	**C MEAN**
T1	Weekly destruction of rosette flower starting at 50 DAE + 3 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE	1.61 (1.03)*	2.50 (1.58)*	6.44 (2.53)*	9.09 (3.01)*	9.74 (3.11)*	10.33 (3.21)*	12.01 (3.47)*	14.72 (3.83)*	8.30 (2.72)
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 liters of water at 10 days interval starting at 50 DAE	2.46 (1.57)	2.50 (1.58)	6.49 (2.54)	9.07 (2.96)	10.83 (3.29)	11.67 (3.41)	12.34 (3.50)	16.94 (4.12)	9.04 (2.87)
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	1.59 (10.3)	1.61 (1.04)	5.73 (2.38)	8.56 (2.92)	6.57 (2.55)	7.07 (2.64)	10.83 (3.27)	10.21 (3.17)	6.52 (2.37)
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/acre at 10 days interval starting at 50 DAE	0.83 (0.53)	1.57 (1.02)	3.99 (1.98)	6.44 (2.53)	6.29 (2.50)	6.33 (2.50)	7.15 (2.65)	9.80 (3.12)	5.30 (2.10)
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	0.76 (0.50)	0.83 (0.53)	2.42 (1.56)	2.46 (1.26)	5.51 (2.34)	3.97 (1.97)	5.83 (2.40)	9.00 (2.98)	3.85 (1.69)
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre alternated with 4 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE	0.00 (0.00)	0.76 (0.50)	0.78 (0.51)	1.63 (1.04)	3.16 (1.75)	1.63 (1.04)	4.67 (2.11)	6.28 (2.50)	2.36 (1.18)
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	1.61 (1.04)	2.42 (1.56)	5.83 (2.40)	8.13 (2.84)	8.13 (2.84)	8.78 (2.95)	12.01 (3.47)	11.43 (3.35)	7.29 (2.56)
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/acre at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	1.67 (1.05)	2.42 (1.56)	6.41 (2.52)	8.80 (2.96)	8.33 (2.85)	9.63 (3.09)	11.92 (3.45)	12.50 (3.52)	7.71 (2.63)
T9	Control	2.48 (1.57)	4.17 (2.02)	8.94 (2.98)	11.67 (3.41)	13.33 (3.65)	14.17 (3.76)	12.50 (3.52)	17.50 (4.18)	10.59 (3.14)
	F test	NS	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE(m) ±	0.432	0.355	0.203	0.284	0.196	0.217	0.213	0.226	0.267
	CD at 5 %	1.29	1.06	0.61	0.85	0.59	0.65	0.64	0.68	0.79
	CV %	80.85	48.64	16.28	19.31	12.29	13.74	11.92	11.47	26.81

Thus, the data so far generated were subjected to proper transformation and then statistically analyzed.

RESULTS AND DISCUSSION

The observations of green fruiting bodies damage were started at 45 days after emergence (DAE) and recorded in Table 1. Treatment T_6 found statistically significant over rest of the treatments from 45 DAE to 122 DAE. The per cent mean green fruiting bodies damage by pink bollworm from 45 DAE to 122 DAE were ranged from 0.68 to 2.01 per cent in which minimum mean green fruiting bodies damage was recorded in treatment T_6 (0.68%) which was followed by T_5 (1.01%) whereas, maximum (2.01%) mean total fruiting bodies damage was observed in control treatment (T_9). The next best treatment was T_4 (1.15%), T_3 (1.31%), T_7 (1.46%) T_8 (1.60 %), T_1 (1.72%), T_2 (1.79%) and T_9 (2.01%).

The green boll damage was recorded at 90 days after emergence (DAE) to 160 DAE recorded in Table 2. Efficacy wise per cent green boll damage was ranged from 3.33-20.00, 3.33-26.67,3.33-30.00, 6.67-33.33, 6.67-36.67, 6.67-40.00, 6.67-46.67, 10.00-50.00 and 10.00-50.00 per cent in T_6, T_5, T_4, T_3, T_7, $T_{8,}$ T_1, T_2 and T_9 respectively. Treatment T_6 was found consistently significant over rest of the treatments from 90 DAE to 160 DAE. The per cent mean green boll damage by pink bollworm from 90 DAE to 160 DAE was ranged from 9.58 - 32.92. Among the treatments, maximum 32.92 per cent mean green boll damage was observed in control treatment (T_9). The minimum per cent mean green boll damage was recorded in T_6 (9.58%) and it was statistically at par with T_5 (13.33%), and T_4 (16.25%). The next promising treatments were T_3 (19.58%), T_7 (22.92%), T_8 (25.00%), T_1 (27.08%), and T_2 (30.00%).

Data on per cent loculi damage were recorded in Table 3 and it revealed that treatment T_6 proved its efficacy over rest of the treatments by recording minimum loculi damage starts from 90 DAE to 160 DAE. The per cent mean data on loculi damage by pink bollworm from 90 DAE to 160 DAE were ranged from 2.36-10.59 among the treatments. However, the per cent mean loculi damage in T_6 (2.36%) was statistically at par with T_5 (3.85%). The next best treatment was T_4 (5.30%) and which is statistically on par with T_3 (6.52%), T_7 (7.29%), T_8 (7.71%), T_1 (8.30%), T_2 (9.04%). Whereas maximum (10.59%). loculi damage by pink bollworm was recorded in control (T_9).

Treatment T_6 found consistently significant over rest of the treatments at the time of harvest (Table 4). The per cent mean open boll damage at harvest by pink bollworm was ranged from 10.83-52.41per cent. Among the treatments maximum 52.41 per cent mean open boll damage was observed in control treatment (T_9). Significantly lower open boll damage was recorded in T_6 (10.83%) which was at par with T_5 (13.10%). The next promising treatments were T_4 (14.42), T_3 (18.32%), T_7 (20.00%), T_8 (22.74%) and T_1 (25.96%). Treatment T_2 recorded higher open boll damage 30.09 per cent among the treatments which was next to the control.

At harvest results revealed that treatment T_6 was significantly superior over control. The per cent mean loculi damage due to pink bollworm were found to be in the range of 3.52-17.45 per cent (Table 5). Treatment T_6 recorded significantly minimum mean loculi damage (3.52%) and was

Table 4. Effects of different treatments on per cent open boll damage at harvest by pink bollworm :

Tr. No.	TREATMENTS	Average boll damage (%)			
		RI	RII	RIII	Mean
T1	Weekly destruction of rosette flower starting at 50 DAE +. 3 sprays of Azadirachtin @ 10 ml/ 10 l at 10 days interval starting at 50 DAE	20.48 (26.91)**	34.56 (36.01)**	22.85 (28.56)**	**25.96 (30.49)****
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 10 days interval starting at 50 DAE	24.56 (29.71)	32.98 (35.05)	32.74 (34.90)	**30.09 (33.22)**
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	14.71 (22.55)	21.62 (27.71)	18.62 (25.56)	**18.32 (25.27)**
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/ ac at 10 days interval starting at 50 DAE	15.56 (23.23)	14.38 (22.28)	13.33 (21.42)	**14.42 (22.31)**
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	11.26 (19.61)	10.80 (19.19)	17.24 (24.53)	**13.10 (21.11)**
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE	13.47 (21.53)	8.33 (16.78)	10.69 (19.08)	**10.83 (19.13)**
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	26.26 (30.83)	14.38 (22.28)	19.35 (26.10)	**20.00 (26.40)**
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/ac at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	19.10 (25.91)	18.65 (25.59)	30.47 (33.50)	**22.74 (28..33)**
T9	Control	50.47 (45.27)	52.63 (46.51)	54.12 (47.36)	**52.41 (46.38)**
	F test	-	-	-	Sig
	SE(m) ±	-	-	—	1.909
	CD at 5 %.	-	-	-	5.72
	CV %	-	-	-	11.78

Table 5. Effects of different treatments on per cent loculi damage by pink bollworm :

Tr. No.	TREATMENTS	Average boll damage (%)			
		RI	RII	RIII	**Mean**
T1	Weekly destruction of rosette flower starting at 50 DAE +. 3 sprays of Azadirachtin @ 10 ml/ 10 l at 10 days interval starting at 50 DAE	6.26 (14.49)**	9.88 (18.32)**	8.44 (16.89)**	**8.19 (16.57)****
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 10 days interval starting at 50 DAE	8.64 (17.09)	10.44 (18.85)	9.67 (18.12)	**9.58 (18.02)**
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	4.24 (11.88)	6.32 (14.56)	5.36 (13.39)	**5.31 (13.28)**
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/ ac at 10 days interval starting at 50 DAE	5.10 (13.05)	4.88 (12.76)	4.64 (12.44)	**4.87 (12.75)**
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	5.02 (12.95)	3.16 (10.24)	6.35 (14.60)	**4.84 (12.59)**
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE	4.99 (12.91)	2.45 (9.01)	3.12 (10.17)	**3.52 (10.70)**
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	7.12 (15.48)	4.59 (12.37)	6.45 (14.71)	**6.05 (14.19)**
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/ac at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	6.25 (14.48)	5.48 (13.54)	9.84 (18.28)	**7.19 (15.43)**
T9	Control	16.21 (23.74)	17.36 (24.62)	18.78 (25.68)	**17.45 (24.68)**
F test					Sig
SE(m) ±					0.957
CD (p=0.05)					2.87
CV (%)					10.79

Table 6. Effect of different treatments on seed cotton yield (q/ha)

Tr.	TREATMENTS	RI	RII	RIII	Yield (q/ha)
T1	Weekly destruction of rosette flower starting at 50 DAE +. 3 sprays of Azadirachtin @ 10 ml/ 10 l at 10 days interval starting at 50 DAE	2.66	2.30	2.72	11.28
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 l of water at 10 days interval starting at 50 DAE	2.96	2.00	1.86	10.00
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	3.02	3.24	2.68	13.13
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/ ac at 10 days interval starting at 50 DAE	3.08	3.42	3.24	14.28
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/ac at an interval of 10 days starting at 50 DAE	3.12	2.69	3.25	16.09
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/ac alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE	3.82	3.78	4.34	17.54
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	2.74	3.18	2.91	12.96
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/ac at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	2.47	2.96	2.61	11.81
T9	Control	1.86	2.34	2.16	9.34
F test					Sig
SE(m) ±					0.191
CD (p=0.05)					0.57
CV (%)					11.52

at par with T_5 (4.84%). The next promising treatment were T_4 (4.87%), T_3 (5.31%), T_7 (6.05%), T_8 (7.19%), T_1 (8.19%), T_2 (9.58%). However, maximum per cent loculi damage (33.68%) was recorded in T_9 – control.

The seed cotton yield in different treatments was ranged from 9.34-17.54 q/ha (Table 6). The highest yield of seed cotton was recorded in T_6 (17.54 q/ha). The next best treatments in which the maximum seed cotton yield obtained was T_5 (16.09 q/ha) followed by T_4 (14.28 q/ha), T_3 (13.13 q/ha), T_7 (12.96 q/ha), T_8 (11.81 q/ha), T_1 (11.28 q/ha) and T_2 (10.00q/ha). In control plot, the lowest seed cotton yield (9.34

Table 7 : Incremental Cost Benefit Ratio of the different treatments :

Tr. No.	Treatments	Cost of the treatments			Total cost (Rs/ha) (A)	Yield (qtl/ha)	Increased yield over control (qtl/ha)	Increased yield over control (Rs/ha) (B)	Net monetory return (Rs/ha) (B-A)	ICBR	Rank
		Cost of insecti-cides (Rs/ha)	Labour charges (Rs/ha)	Equip-ment charges (Rs.)							
T1	Weekly destruction of rosette flower starting at 50 DAE + 3 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE.	840	440+660 = 1100	150	2090	11.28	1.94	9991	7901	1 : 3.78	VI
T2	Weekly destruction of rosette flower + 3 sprays of *Beauveria bassiana* 1.15 @ 40 g/10 liters of water at 10 days interval starting at 50 DAE	1200	440+660 = 1100	150	2450	10.00	0.66	3399	949	1 : 0.38	VIII
T3	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	2000	440+1100 =1540	100	3640	13.13	3.79	20445	15878	1 : 4.36	IV
T4	Weekly destruction of rosette flower + 7 releases of trichocards @ 3 cards/acre at 10 days interval starting at 50 DAE	2800	440+1540 =1980	130	4910	14.28	4.94	25441	20531	1 : 4.18	V
T5	Weekly destruction of rosette flower + 9 releases of trichocards @ 3 cards/acre at an interval of 10 days starting at 50 DAE	3600	440+1980 =2420	160	6180	16.09	6.75	34762	28852	1 : 4.62	II
T6	Weekly destruction of rosette flower + 5 releases of trichocards @ 3 cards/acre alternated with 4 sprays of Azadirachtin @ 10 ml/10 liters at 10 days interval starting at 50 DAE	2000 + 1120 = 3120	440+1980 =2420	100+200 =300	5840	17.54	8.20	42230	36390	1 : 6.23	I
T7	Weekly destruction of rosette flower starting at 50 DAE + 4 alternate sprays of Azadirachtin @10 ml and *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 10 days interval starting at 50 DAE	1120 + 1600) = 2720	440+1760 =2200	200+200 = 400	5320	12.96	3.62	18643	13323	1 : 2.50	VII
T8	Weekly destruction of rosette flower starting at 50 DAE + spray of Azadirachtin @ 10 ml at 60 DAE + releases of trichocards @ 3 cards/acre at 70 DAE + spray of *Beauveria bassiana* 1.15 @ 40 g/10 litres of water at 80 DAE	280 + 400 + 400 =1080	440+660 =1100	50+50+50 = 150	2330	11.81	2.47	12720	10390	1 : 4.45	III
T9	Control	-	-	-	-	9.34	-	-	-	-	IX

q/ha) was recorded.

It seems that the treatment T_6 - was most cost effective in the order to merit with highest ICBR (1:6.23) with highest net monetary return of Rs 36390/ ha followed by T_5 - with ICBR (1:4.62) with net monetary return of Rs 28852 / ha and T_8- with ICBR (1:4.45) and net monetary return of Rs 10390 / ha. The next effective treatment was T_3- with ICBR (1:4.36) and T_4 - with ICBR of (1:4.18) However, among the different treatments T_2 - recorded the lowest ICBR (1:0.38) with lowest net monetary return of Rs. 949 and found least cost effective treatment (Table 7).

CONCLUSION

From the data overall it was concluded that weekly destruction of rosette flowers followed by 5 releases of trichocards @ 3 cards/ ac alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE provided maximum protection from pink bollworm damage in *Bt* cotton. As the number of sprays decreases pink bollworm damage increases. However, on the basis of cost benefit ratio weekly destruction of rosette flower followed by 5 releases of trichocards @ 3 cards/ ac alternated with 4 sprays of Azadirachtin @ 10 ml/10 l at 10 days interval starting at 50 DAE were found economical.

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Relationship of weather parameters with population of pink bollworm (*Pectinophora gossypiella*) in cotton

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Cotton is the most important crop producing natural fibre which has been under commercial cultivation for domestic consumption and export needs of about 111 countries in the world and hence called "King of fibres" or "White gold". India is an important grower of cotton on a global scale. In India, cotton is cultivated on an area of 126.55 lakh ha with 400 lakh bales production of cotton with an average productivity of 537 kg/ha.

The crop is attacked by 1326 species of insect pests throughout the world, of which about 130 different species of insects and mites found to devour cotton at different stages of crop growth in India. 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 Cry 1 Ac in western India (Bapla, 2010). Among the bollworms, pink bollworm assumed major pest status in recent past (Ghosh, 2001).

Worldwide, pink bollworm *Pectinophora gossypiella* (Saunders) has become economically the most destructive pest of cotton and has known to cause 2.8 to 61.9 per cent loss in seed cotton yield, 2.1 to 47.1 per cent loss in oil content and 10.7 to 59.2 per cent loss in normal opening of bolls (Patil, 2003). Locule damage was noted to an extent of 55 per cent and 35-90 per cent reduction in seed cotton yield was reported by Narayanan (1962). Agarwal and Katiyar (1979) estimated the yield loss to an extent of 6525 MT annually.

MATERIALS AND METHODS

Department of Agriculture, Government of Maharashtra sponsored project "Crop Pests Surveillance and Advisory Project (CROPSAP)" on ICT based e-pest surveillance and advisory. The main object is to monitor the pest in cotton, issue the pest advisories timely to extension agencies and farmers, disseminate the IPM activities across the state.

Observations were recorded from fixed plots of different villages. Fixed plots selected were minimum of one acre in area and observations were started from 60 days after sowing of cotton crop. Upto 10 days old bolls were selected for observations. One boll from each randomly selected ten plants were observed for pink bollworm infestation and average of 10 bolls were calculated.Weather parameters like minimum and maximum temperature, morning and evening relative humidity and rainfall were recorded in meteorological observatory of

Table 1. Population dynamics of pink bollworm in Nanded during 2017-2018

SMW	Week period	No of larvae/ 10 bolls	Rainfall	Temperature °C		Relative humidity (%)	
				Max	Min	B.N.	A.N.
31	31 July - 05 August	0.13	7.6	32.0	18.7	66.8	51.0
32	6 - 12 August	0.06	63.8	31.0	17.0	77.6	60.0
33	13-19 August	0.21	13.0	30.0	16.6	76.6	58.7
34	20-26 August	0.23	264.4	28.1	17.0	76.9	61.3
35	27 Aug - 2 Sept	0.17	46.0	30.6	18.0	78.9	57.6
36	3 - 9 September	0.12	6.0	31.9	18.9	76.6	52.3
37	10 - 16 Spetember	0.10	13.2	31.9	18.9	75.7	56.7
38	17 - 23 Spetember	0.05	80.6	30.6	18.9	75.4	56.7
39	24 - 30 September	0.03	0.0	33.6	19.1	62.1	45.3
40	1 - 7 October	0.22	3.4	33.0	18.3	72.6	53.0
41	8 - 14 October	0.04	6.2	31.7	18.0	71.7	47.1
42	15 -21 October	0.08	6.4	32.1	21.3	71.1	44.4
43	22 - 28 October	0.15	9.2	32.0	21.3	69.3	39.4
44	29 Oct - 4 Nov	0.16	0.0	32.1	23.0	68.6	35.6
45	5 - 11 November	0.30	0.0	31.6	22.9	74.0	36.3
46	12 - 18 November	1.24	0.0	30.2	18.9	72.9	47.4
47	19 - 25 November	1.90	0.0	30.6	19.3	75.4	37.0
48	26 Nov - 02 Dec	2.52	0.0	30.9	16.9	66.6	28.0
49	03 - 09 December	2.36	0.0	29.8	16.0	61.1	34.4
50	10 - 16 December	5.17	0.0	30.1	18.4	53.3	29.0
51	17 - 23 December	6.65	0.0	29.3	16.3	61.3	28.1
52	24 - 31 December	6.27	0.0	29.6	12.5	68.1	31.5

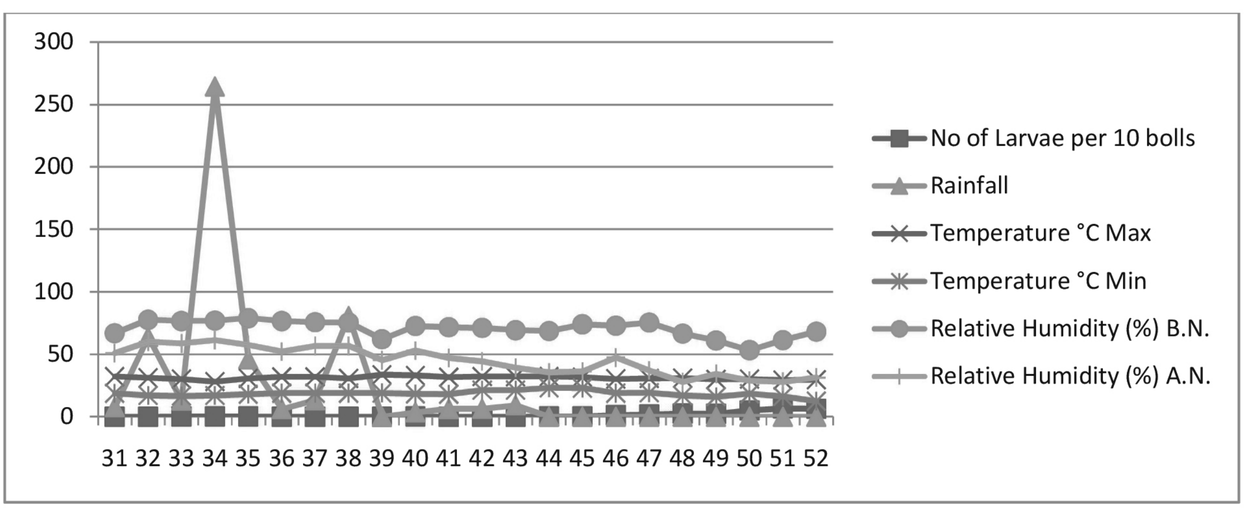

Fig. 1 : Population dynamics of pink bollworm in Nanded during 2017-2018

Table 2. Population dynamics of pink bollworm in Parbhani during 2017-2018

SMW	Week period	No of larvae/ 10 bolls	Rainfall	Temperature °C		Relative humidity (%)	
				Max	Min	B.N.	A.N.
31	31 July - 05 August	0.36	0.0	33.4	22.8	75.0	49.0
32	6 - 12 August	0.43	16.1	32.2	23.0	85.0	59.0
33	13-19 August	0.71	141.0	28.7	22.7	92.0	77.0
34	20-26 August	0.21	98.2	29.2	9.4	90.0	77.0
35	27 Aug - 2 Sept	0.14	29.8	17.4	9.6	88.0	67.0
36	3 - 9 September	0.14	78.9	13.7	22.7	82.0	60.0
37	10 - 16 Spetember	0.14	79.2	30.5	22.7	87.0	72.0
38	17 - 23 Spetember	0.42	6.6	31.5	22.3	87.0	61.0
39	24 - 30 September	0.07	0.0	34.2	22.5	77.0	48.0
40	1 - 7 October	0.05	57.6	33.2	21.6	82.0	65.0
41	8 - 14 October	0.04	111.2	31.2	22.2	89.0	69.0
42	15 -21 October	0.02	1.4	32.6	20.2	79.0	46.0
43	22 - 28 October	0.05	0.0	32.6	16.4	77.0	32.0
44	29 Oct - 4 Nov	0.07	0.0	30.9	14.5	78.0	31.0
45	5 - 11 November	0.04	0.0	30.8	12.2	79.0	31.0
46	12 - 18 November	1.06	0.0	31.4	14.4	76.0	32.0
47	19 - 25 November	1.57	0.0	32.0	17.0	77.0	42.0
48	26 Nov - 02 Dec	2.97	0.0	29.9	10.2	77.0	31.0
49	03 - 09 December	2.58	0.0	30.4	14.4	75.0	42.0
50	10 - 16 December	2.73	0.0	31.0	12.5	78.0	31.0
51	17 - 23 December	3.64	0.0	29.3	7.9	75.0	27.0
52	24 - 31 December	3.84	0.0	25.6	6.1	67.0	19.0

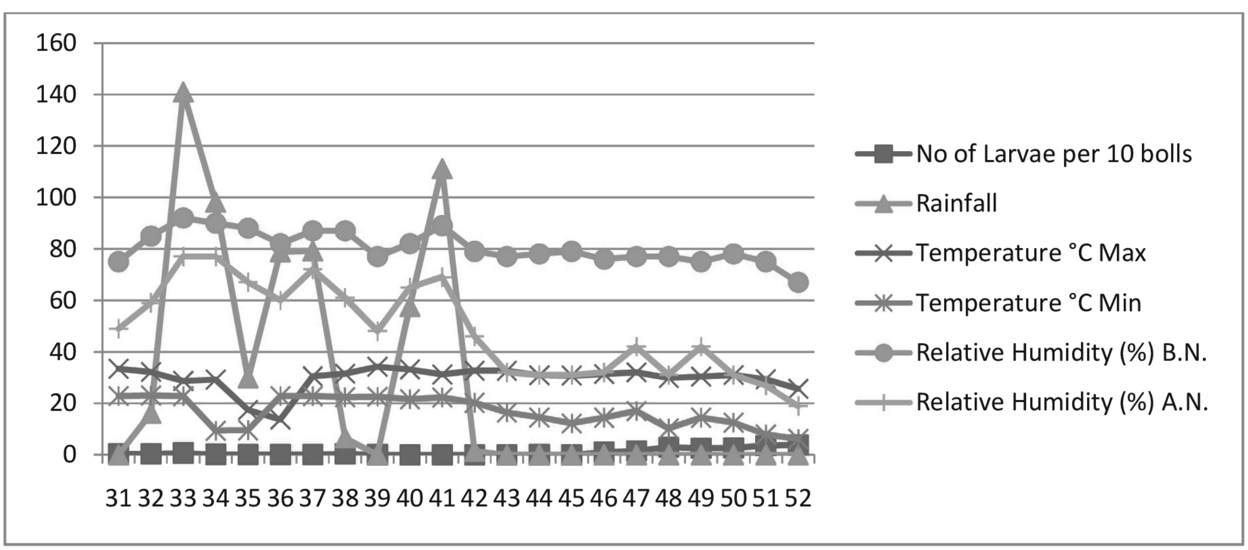

Fig. 2. Population dynamics of pink bollworm in Parbhani during 2017-2018

Table 3. Population dynamics of pink bollworm in Nanded during 2018-2019

SMW	Week period	No of larvae/ 10 bolls	Rainfall	Temperature °C		Relative humidity (%)	
				Max	Min	B.N.	A.N.
31	31 July - 05 August	0.51	12.0	31.2	17.7	81.1	72.9
32	6 - 12 August	0.77	35.8	29.1	14.9	80.0	83.3
33	13-19 August	0.88	145.2	27.9	15.7	77.0	79.0
34	20-26 August	0.55	144.2	29.3	15.0	30.1	74.9
35	27 Aug - 2 Sept	0.58	34.6	29.9	14.6	84.9	73.6
36	3 - 9 September	0.44	4.8	31.1	15.3	78.3	64.4
37	10 - 16 Spetember	0.32	0.0	32.9	17.6	81.0	61.6
38	17 - 23 Spetember	0.42	35.8	30.9	19.0	76.0	69.4
39	24 - 30 September	0.14	15.6	33.0	19.9	73.1	62.6
40	1 - 7 October	0.17	0.0	33.0	20.4	75.6	67.1
41	8 - 14 October	0.16	0.0	34.1	19.9	73.3	66.1
42	15 -21 October	0.02	0.0	34.0	19.6	66.9	58.7
43	22 - 28 October	0.01	0.0	33.3	21.7	70.7	64.0
44	29 Oct - 4 Nov	0.06	0.0	32.7	18.7	65.0	60.0
45	5 - 11 November	0.02	0.0	33.7	22.4	75.7	61.7
46	12 - 18 November	0.31	0.0	32.4	15.6	58.7	54.3
47	19 - 25 November	0.16	0.0	32.1	15.9	71.4	61.0
48	26 Nov - 02 Dec	0.05	0.0	30.7	14.4	64.6	55.6
49	03 - 09 December	0.09	0.0	31.1	14.7	70.6	61.7
50	10 - 16 December	0.04	0.0	29.4	13.9	69.3	60.6
51	17 - 23 December	0.02	0.0	25.9	9.4	69.7	65.4
52	24 - 31 December	0.11	0.0	27.6	10.5	58.4	49.9

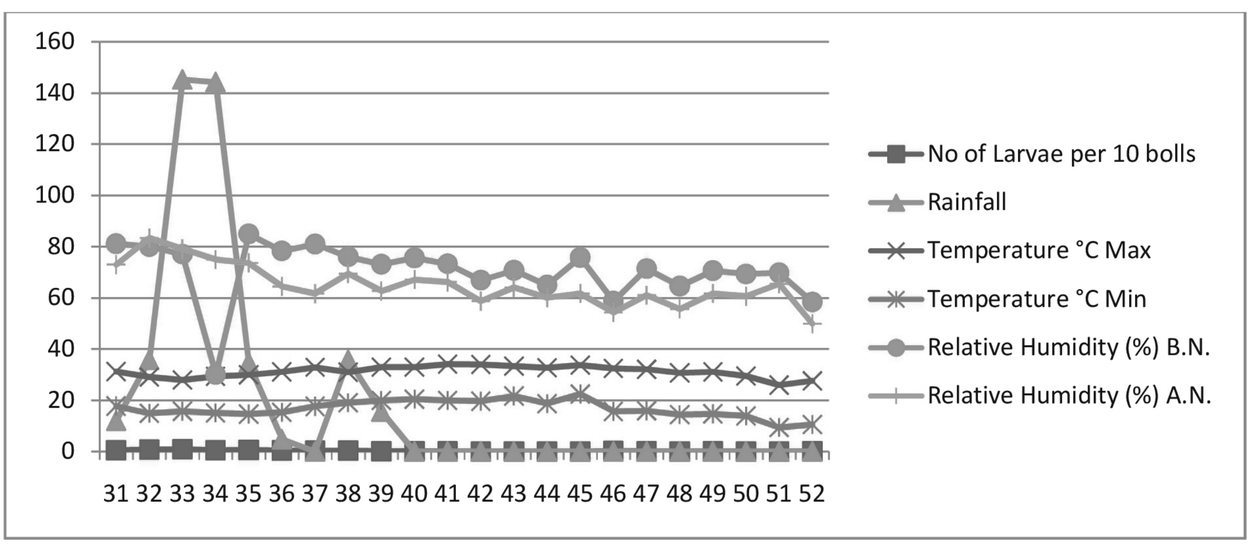

Fig. 3. Population dynamics of pink bollworm in Nanded during 2018-2019

Table 4. Population dynamics of pink bollworm in Parbhani during 2018-2019

SMW	Week period	No of larvae/ 10 bolls	Rainfall	Temperature °C		Relative humidity (%)	
				Max	Min	B.N.	A.N.
31	31 July - 05 August	1.82	0.0	32.8	21.7	79.0	50.0
32	6 - 12 August	2.23	7.2	30.5	22.0	84.0	68.0
33	13-19 August	1.37	148.4	28.3	21.5	90.0	75.0
34	20-26 August	0.42	110.2	28.7	20.5	91.0	73.0
35	27 Aug - 2 Sept	0.37	8.8	29.7	20.8	84.0	61.0
36	3 - 9 September	0.51	2.4	30.9	20.2	83.0	54.0
37	10 - 16 Spetember	0.37	0.0	33.0	20.7	83.0	49.0
38	17 - 23 Spetember	0.11	1.8	32.4	21.2	83.0	56.0
39	24 - 30 September	0.08	4.0	34.6	20.8	82.0	41.0
40	1 - 7 October	0.05	0.0	34.9	20.0	78.0	40.0
41	8 - 14 October	0.04	0.0	35.5	16.3	72.0	20.0
42	15 -21 October	0.00	0.0	34.5	16.5	75.0	27.0
43	22 - 28 October	0.00	0.0	34.7	16.2	72.0	26.0
44	29 Oct - 4 Nov	0.00	0.0	32.9	14.8	73.0	30.0
45	5 - 11 November	0.00	0.0	33.9	16.3	71.0	33.0
46	12 - 18 November	0.01	0.0	33.3	11.4	75.0	23.0
47	19 - 25 November	0.25	0.0	32.2	16.3	77.0	35.0
48	26 Nov - 02 Dec	0.04	0.0	30.4	10.2	77.0	24.0
49	03 - 09 December	0.00	0.0	31.0	14.3	76.0	35.0
50	10 - 16 December	0.00	0.0	30.3	13.5	75.0	34.0
51	17 - 23 December	0.00	0.0	27.1	9.9	76.0	34.0
52	24 - 31 December	0.00	0.0	28.5	8.5	75.0	21.0

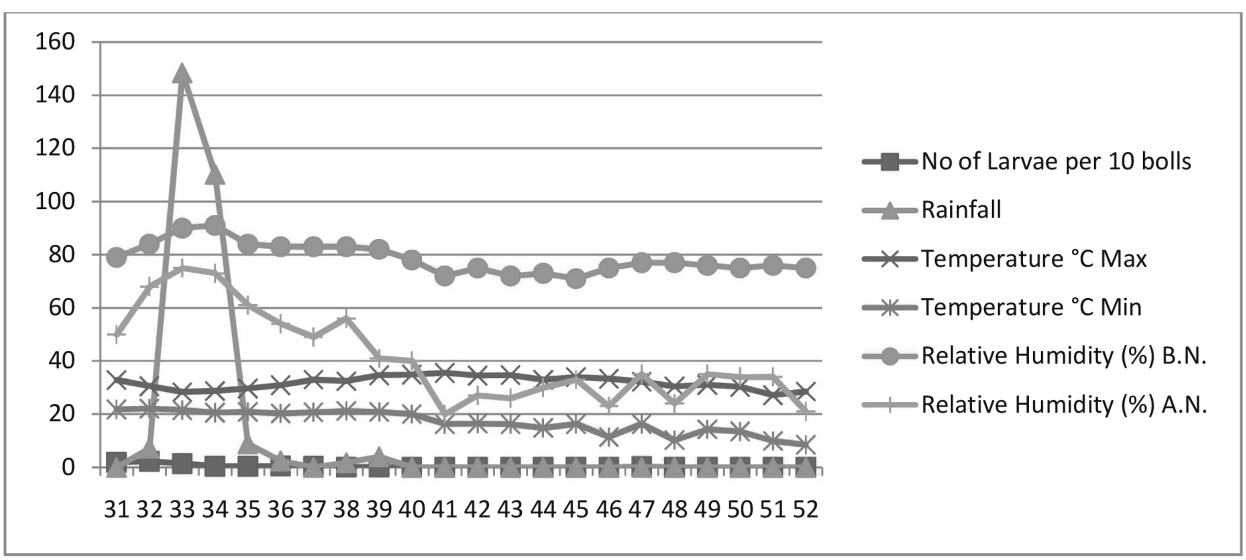

Fig. 4. Population dynamics of pink bollworm in Parbhani during 2018-2019

Parbhani and Nanded.

The average data of pink bollworm infestation and weather factors were subjected to correlation and regression analysis to work out the relationship between pests incidence and weather parameters.

RESULTS AND DISCUSSION

The larval population of *Pectinophora gossypiella* was recorded from 31st SMW (31st July - 05th August) to 52nd SMW (24th – 31st December) during 2017-2018 and 2018-2019.

During 2017-2018 and 2018-2019 the peak incidence of pink bollworm larvae were (Table 2 and 4) observed during 52nd and 32nd SMWs, respectively in Parbhani district. In Nanded district the maximum population of pink bollworm larvae during 2017-2018 and 2018-2019 were recorded in 51st and 33rd SMWs respectively (Table 1 and 3).

The minimum population of pink bollworm were recorded during 2017-18 in 42nd SMW and during 2018-19 in 42nd to 45th and 49th to 52nd SMWs at Parbhani district (Table 2 and 4). However in Nanded district the minimum incidence of pink bollworm were recorded during 2017-18 in 39th SMW and during 2018-19 in 42nd, 45th and 51st SMWs (Table 1 and 3).

Table 5. Correlation of weather parameters with pink bollworm (2017-18 and 2018-19)

Weather param-eters	Correlation coefficient ('r' value) for pink bollworm)			
	Parbhani		Nanded	
	2017-2018	2018-19 2019	2017-2018	2018-2019
T max	-0.036	-0.233	-0.527	-0.368
T min	-0.636	0.571**	-0.562	-0.158
RH I	-0.589	0.525**	-0.623	0.157
RH II	-0.603	0.667**	-0.711	0.798**
Rainfall	-0.362	0.341	-0.228	0.721**

** Significant at 1%

The correlation studies (Table 5) indicated that the associations of pink bollworm larvae with weather parameters were negative as well as not significant during 2017-18 in both the districts. Minimum temperature (r = 0.571), morning relative humidity (r=0.525) and evening relative humidity (r= 0.667) showed highly positive significant correlation during 2018-19 in Parbhani district. There was positive correlation with rainfall during 2018-19 in Parbhani district.

However during 2018-19 in Nanded district the relation of pink bollworm with evening relative humidity (r= 0.798) and rainfall (r= 0.721) have highly positive significant correlation. The morning relative humidity is having positive correlation with pink bollworm larvae during 2018-19 in Nanded district.

The present findings are in agreement with the findings of Vennila *et al.* 2011 who had given thumb rule for prediction of pink bollworm population using weather parameters.

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Biosynthesis of green zinc nanoparticles and its effect on sucking pests of *Bt* cotton

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Bt cotton is genetically modified cotton plant in which cry 1 Ac gene from *Bacillus thuringiensis* (a common soil bacterium) is introduced through genetic engineering. The target insect for cry 1 Ac toxin protein have been lepidopteran pest like *Helicoverpa* spp and not the sucking pest, which also cause considerable damage in cotton and need to be managed through insecticides.

The sucking pests have become a serious problem in *Bt* cotton. These pests not only cause direct losses to the crops but also an increase the number of sprays that leads to resurgence of minor pests and elimination of natural enemies. Imidacloprid 60 FS can manage these sucking pests effectively on the contrary sucking pests have developed resistance to Imidacloprid 17.8 SL. Further, Imidacloprid 17.8 SL affects the beneficial insects like honey bees and other natural enemies, therefore there is need for eco-friendly alternative tool for the management of sucking pest.

Cotton aphids are the most serious pests of cotton all over the world (Rummel *et al.,* 1995). Cotton aphids feeding can stimulate foliar alterations, delay of the plant growth, fewer fruit setting, lower fruit retention and reduced cotton lint weight (Raboudi *et al.,* 2002).

During 2006, the mealybug, *Phenacoccus solenopsis* caused economic damage, reduced yields by up to 40-50 per cent in an infested fields in several parts of Gujarat (Nagrare *et al.,* 2009).

Among the several avenues to overcome the insecticidal resistance problem, replacement with new molecules of insecticide is one of the important considerations. The use of green nanoparticles is one such new avenue for pest management. Therefore, evaluation of synthesised green nanoparticles having a novel mode of action for their toxicity and efficacy against aphids and mealybugs is necessary. There is limited information on use of green nanoparticles for cotton aphid and mealybug . In this view the present study is undertaken with the following objectives.

MATERIALS AND METHODS

Biosynthesis of zinc oxide nanoparticles from spinach (*Spinacia oleracea*) leaves : The biosynthesis of zinc oxide nanoparticles from spinach leaves (*Spinacia oleracea*) was carried out as described below.

Preparation of spinach leaves extract : The spinach leaves were washed thoroughly with distilled water and dried using a solar tunnel dryer. The dried leaves were ground using a pulverizer to make into a fine powder and passed through a 100 mesh sieve (150 µm).

Biosynthesis of zinc oxide nanoparticles : The leaves extract of spinach (50 ml) was boiled at 60-80 °C using magnetic stirrer. Zinc nitrate hexahydrate [$Zn(NO_3)_2.6H_2O$] was used as a precursor. 1 mM zinc nitrate solution was prepared using distilled water. The solution was added to the leaf extract when temperature reached to 60 °C and boiled for 30 min or until colour changed. A change in the colour from dark green to pale yellow indicates the formation of zinc oxide nanoparticles (Amrita *et al.*, 2015). The size of the biosynthesized zinc oxide nanoparticles extracted from spinach leaves (*Spinacia oleracea*) were reduced by centrifugation and ultrasonication.

RESULTS AND DISCUSSION

Mortality of aphids caused by zinc oxide nanoparticles : Zinc oxide nanoparticles derived out of spinach leaves was tested at five different dosages like 250, 500, 1000, 1500 and 2000 ppm against cotton aphid, *A. gossypii,* cotton and mealybug, *P. solenopsis*

Effect of zinc oxide green nanoparticles against cotton aphid was studied in bioassay mode in comparison with the metal form of the same compound at various dosages. The results revealed that as concentration of zinc oxide green nanoparticles increased from 250 ppm to 2000 ppm the mortality ranged from 23.33 to cent per cent(Table1). At one day after treatment green ZnO nanoparticle @ 2000 ppm registered highest per cent mortality of 43.33 among the different concentration of green nanoparticle and the metal from at the same concentration recorded 50.00 per cent mortality. The similar trend was observed at three days after treatment where green nanoparticle and metal nanoparticles @ 2000 ppm recorded 63.33 and 80.00 per cent mortality. From this we can assume that the green nanoparticle synthesized from plant products contain impurities so they reduce the toxicity of green nanoparticles compare to the metal nanoparticles. The cent per cent mortality was observed at five days after treatment in both green and metal nanoparticle @ 2000 ppm proving their efficacy which was *on par* with chemical check dinotefuran (20 %) SG @ 0.30 g/l .

In accordance with present findings Rouhani *et al.*, (2012) reported that the insect mortality increased significantly with increase in pesticide concentrations. Although insect mortality as a result of using nanoparticles was slightly less than imidacloprid (Guan *et al.*, 2008; Samih *et al.*, 2011, Rouhani *et al.*, 2011), one advantage of using them is low risk of developing resistance in long term usage. Ghidan *et al.,* (2017) investigated that cent per cent mortality of all stages of aphids was attained at concentration of 8000 µg/ml of ZnO nanoparticles after 48 h treatment. .

Mortality of mealybugs caused by zinc oxide nanoparticles : Effect of zinc oxide green nanoparticles against cotton mealybug was studied in bioassay mode in comparison with the metal form of the same compound at various dosages. The results revealed that as concentration of zinc oxide green nanoparticles increased from 250 to 2000 ppm the mortality ranged from 20 to 90 per cent (Table 2).The green

Table 1. Effect of zinc oxide nanoparticles on cotton aphid, *Aphis gossypii*

Treatment details	Dosage	Per cent mortality of mealybugs at different intervals		
		1 DAT	3 DAT	5 DAT
T_1: Green ZnO nanoparticle	250 ppm	23.33(28.88)^{i*}	40.00(39.23)^{i}	53.33(46.91)^{i}
T_2: Metal ZnO nanoparticle	250 ppm	26.67(31.09)^{h}	46.67(43.09)^{h}	60.00(50.77)^{h}
T_3: Green ZnO nanoparticle	500 ppm	30.00(33.21)^{g}	46.67(43.09)^{h}	63.33(52.73)^{g}
T_4: Metal ZnO nanoparticle	500 ppm	33.33(35.26)^{f}	50.00(45.00)^{g}	66.67(54.74)^{f}
T_5: Green ZnO nanoparticle	1000 ppm	36.67(37.27)^{e}	53.33(46.91)^{f}	70.00(56.79)^{e}
T_6: Metal ZnO nanoparticle	1000 ppm	43.33(41.17)^{c}	56.67(48.83)^{e}	76.67(61.12)^{d}
T_7: Green ZnO nanoparticle	1500 ppm	40.00(39.23)^{d}	56.67(48.83)^{e}	83.33(65.91)^{c}
T_8: Metal ZnO nanoparticle	1500 ppm	46.67(43.09)^{b}	66.67(54.74)^{c}	90.00(71.57)^{b}
T_9: Green ZnO nanoparticle	2000 ppm	43.33(41.17)^{c}	63.33(52.73)^{d}	100.00(90.00)^{a}
T_{10}: Metal ZnO nanoparticle	2000 ppm	50.00(45.00)^{a}	80.00(63.43)^{b}	100.00(90.00)^{a}
T_{11}: Dinotefuran 20 % SG	0.30 g/l	46.67(43.09)^{b}	100.00(90.00)^{a}	100.00(90.00)^{a}
T_{12}: Untreated control	—	0.00(0.00)^{j}	3.33(10.52)^{j}	6.67(14.96)^{j}
S.Em±	0.10	0.26	0.22	
CD (p=0.05)	0.39	1.03	0.87	

n=30 second instar nymphs DAT- Days after treatment

*Figures in the parentheses are “arcsine” transformed values

Means followed by same letters in a column are not significantly different (P=0.01) by DMRT

Table 2. Effect of zinc oxide nanoparticles on cotton mealybug, *Phenacoccus solenopsis*

Treatment details	Dosage	Per cent mortality of mealybugs at different intervals		
		1 DAT	3 DAT	5 DAT
T_1: Green ZnO nanoparticle	250 ppm	20.00(26.57)^{i*}	33.33(35.26)^{j}	46.67(43.09)^{k}
T_2: Metal ZnO nanoparticle	250 ppm	23.33(28.88)^{h}	40.00(39.23)^{i}	53.33(46.91)^{j}
T_3: Green ZnO nanoparticle	500 ppm	26.67(31.09)^{g}	43.33(41.17)^{h}	56.67(48.83)^{i}
T_4: Metal ZnO nanoparticle	500 ppm	30.00(33.21)^{f}	46.67(43.09)^{g}	63.33(52.73)^{h}
T_5: Green ZnO nanoparticle	1000 ppm	33.33(35.26)^{e}	50.00(45.00)^{f}	70.00(56.79)^{g}
T_6: Metal ZnO nanoparticle	1000 ppm	36.67(37.27)^{d}	56.67(48.83)^{e}	73.33(58.91)^{f}
T_7: Green ZnO nanoparticle	1500 ppm	36.67(37.27)^{d}	56.67(48.83)^{e}	83.33(65.91)^{d}
T_8: Metal ZnO nanoparticle	1500 ppm	40.00(39.23)^{c}	60.00(50.77)^{d}	80.00(63.43)^{e}
T_9: Green ZnO nanoparticle	2000 ppm	40.00(39.23)^{c}	66.67(54.74)^{c}	90.00(71.57)^{c}
T_{10}: Metal ZnO nanoparticle	2000 ppm	43.33(41.17)^{b}	76.67(61.12)^{b}	93.33(75.04)^{b}
T_{11}: Buprofezin 25 SC	1.00 ml/l	46.67(43.09)^{a}	83.33(65.91)^{a}	100.00(90.00)^{a}
T_{12}: Untreated control	—	0.00(0.00)^{j}	0.00(0.00)^{k}	3.33(10.52)^{l}
S.Em±	0.17	0.15	0.19	
CD (p=0.05)	0.67	0.60	0.76	

n=30 second instar nymphs DAT- Days after treatment

*Figures in the parentheses are “arcsine” transformed values

Means followed by same letters in a column are not significantly different (P=0.01) by DMRT

ZnO nanoparticle @ 2000ppm recorded 40.00 per cent mortality and the similar mortality was recorded by metal ZnO nanoparticle @ 1500 ppm at one day after treatment. At three days after treatment green and metal nanoparticle @ 2000 ppm caused 66.67 and 76.67 per cent mortality respectively and at five days after treatment 90.00 to 93.33 per cent mortality was registered by both nanoparticles at same concentration. This confirms that five days after treatment maximum mortality of mealybugs could be achieved @ 2000 ppm .

Effectiveness of green zinc oxide nanoparticles may be attributed to the damage to the protective wax coat on the cuticle of insects, both by sorption and abrasion so that the insects begin to lose water and die due to desiccation (Arumugam *et al.,* 2016).

CONCLUSION

Green zinc nanoparticles synthesised from spinach leaves proves to be an alternative to chemical pesticides to avoid resistance and resurgence problem due to sucking pest in *Bt* cotton

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Sudden wilt in cotton: Prominent factors contributing to its occurrence in north India

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ABSTRACT : The occurrence of sudden wilt problem in cotton in north India is increasing since last one decade. It has been established that parawilt/ sudden wilt is a physiological disorder in which the soil–plant–atmosphere continuum is broken due to adverse environmental factors like soil saturation which results in poor root growth and reducing oxygen influx as a principal cause of injury to roots and the shoots. However, the studies on primary factors responsible for occurrence of these situations in cotton fields are merely available. Hence, to understand the factors responsible for sudden wilt, field data were collected during the month of July to November 2017 and 2018 from Rajasthan, Haryana and Punjab. Among all 29.7 per cent cotton fields showed typical sudden wilting from the month of September onwards during 2018-19. These 29.7 per cent fields were practiced no deep ploughing, cotton-wheat-cotton cropping system more than the past 5 years and early irrigation (before 30 DAS). The soil EC and pH in these fields were ranged between 2.5 to 4.5 dS/m and 7.6 to 7.9, respectively. The cotton fields where farmers have adopted crop rotations, crop residue incorporation, deep ploughing, timely irrigation etc. resulted better crop with deep rooted system (>30 cm) and sudden wilting was not observed. Sudden wilting situation was more prominent in early maturing and high yielding Bt hybrids during first fortnight of September. The root depth in these fields was ranged between 10-20 cm with higher root density in first 10 cm layer 21-50% fields and 20-30 cm root depth in 50-67.5 per cent fields. These practices and soil health situations appeared to be the prominent factors contributing to the poor root development and occurrence of sudden wilt at great grand growth stage of cotton crop (125-160 DAS). This situation also enhanced vulnerability of cotton crop to biotic problems such as root rot; nematodes, fungal foliar spots (71.4%), and termites/root rot (28.6%). Hence, to manage these problems, a large and deep root system should be developed as quickly as possible and shoot growth should be controlled before the plants enter the reproductive growth stage so as to achieve potential yield.

Apart from the soil borne fungal and CLCuV diseases a physiological disorder “sudden wilt” known as parawilt is increasing threat to the cotton production both in North and central India (Hebber and Mayee 2004). Past research has established that, in sudden wilt, the soil–plant–atmosphere continuum is broken due to adverse environmental factors like soil saturation/water logging which results in poor root growth and slowing of oxygen influx is the principal cause of injury to roots and the shoots (Vertapetian *et al.,* 1977). During water logging situations, the rate of water intake by roots fell by 60 per cent within 1 hour of flooding, as the primary roots and root hairs are damaged soon after flooding and roots cannot survive more than 30 min of O_2 deficiency (Huck 1970, Karmar and Jackson 1954). Cotton plant at its great grand growth stage together with bright sunshine further enhances stomatal conductance, transpiration and photosynthesis, which is an important prerequisite for sudden wilt. The high transpiration loss of water in fully grown plant demands more uptake of water and nutrient, however, damaged or poor root system function under water logging results in collapse of the soil–plant–atmosphere continuum. Thus, the mismatch between the uptake and loss of water through the roots and leaves transpiration, respectively causes sudden wilt in cotton (Denis *et al.,* 2000; Vertapetian et al., 1977). Its occurrence may also depend on the condition of the plants, in fact being much more severe if the cotton has been growing rapidly (Hebbar and Mayee 2011).

Such types of problems have also been reported in the North Indian cotton growing zone where the field situations are different from central India and generally water logging/ soil saturation conditions do not arise except during heavy rainfall or heavy flood irrigation. Also, the soils of central and south zone are mostly black basalt soil and red soil with less to medium organic carbon, large amount of clay and humus, while in north zone, soils are alluvial soils with silt, clay, sand, gravel and less organic carbon level. This indicates that the situations reported for sudden wilt/parawilt occurrence in previous studies may differ under the north zone conditions, and there may be some other factors responsible for conditions leading to the mismatch between the uptake of water through the roots and transpiration loss of water through the leaves which is resulting in sudden wilt. Moreover, there may be some issues related to soil health and cultural practices which may ameliorate such situation to occur sudden wilt under field condition in north cotton growing zone. These conditions which are ameliorating such situation to occur sudden wilt especially at its great grand growth stage during the month of August –September (120-160 days after sowing) have not been studied or merely available. Hence, the present study was conducted to estimate the area under sudden wilt problem and to understand the field situations and cultural practices which are ameliorating sudden wilt in North Indian cotton growing areas.

MATERIALS AND METHODS

Survey and data collection : Field survey was conducted during the month of July to November 2017 and 2018 to collect the data on parawilt/sudden wilt incidence in Rajasthan (Hanumangarh, Sriganganagar), Haryana (Sirsa, Fatehabad, Hisar) and Punjab (Mansa, Abohar, Bathinda). The data were recorded from 50 farmer's fields in 2-3 villages in each district. Data on incidence sudden wilt and root rot were collected from randomly selected 100 plants across a diagonal in each of the fields. Fields were kept under observation throughout growing season. During the survey disease incidence percent was assessed on the basis of plant affected in the sampled area. In addition to the data collection on occurrence of parawilt and root rot, the base line data on soil fertility, cropping history, problem/disease history, irrigation, soil health management, cultural practices and the crop management practices being followed the farmers and their results were collected. The data were pooled and probability analysis was done to correlate the problem and the basic or preliminary cause.

RESULTS AND DISCUSSION

The root rot incidence in farmer's fields was recorded to be ranging from 0-75 per cent in Haryana and 0-15 per cent in Rajasthan and 0-5 per cent in Punjab during 2017-18. However, among the fields such type of wilting problems were observed with 28.3 per cent root rot and nematode infection, 15.8 per cent root rot, 7.2 per cent root rot and termites and in 26.5 per cent fungal foliar spots (Fig. 1).

Among all surveyed fields, 57.7 per cent farmers have followd cotton-wheat-cotton croppng system more than 5 years, 46.2 per cent have not applied FYM/manure, 38.5 per cent have not done deept ploughing, and 84.4 per cent have used laser leveling. Cotton root system in these 50 per cent fields was observed to be with poor growth (10-20 cm soil layer) and in 50 per cent it was with medium growth (20-30 cm soil layer). Apart from these in 38.5 per cent fields the parellel roots were observed in 10-15 cm layer (Fig.2).

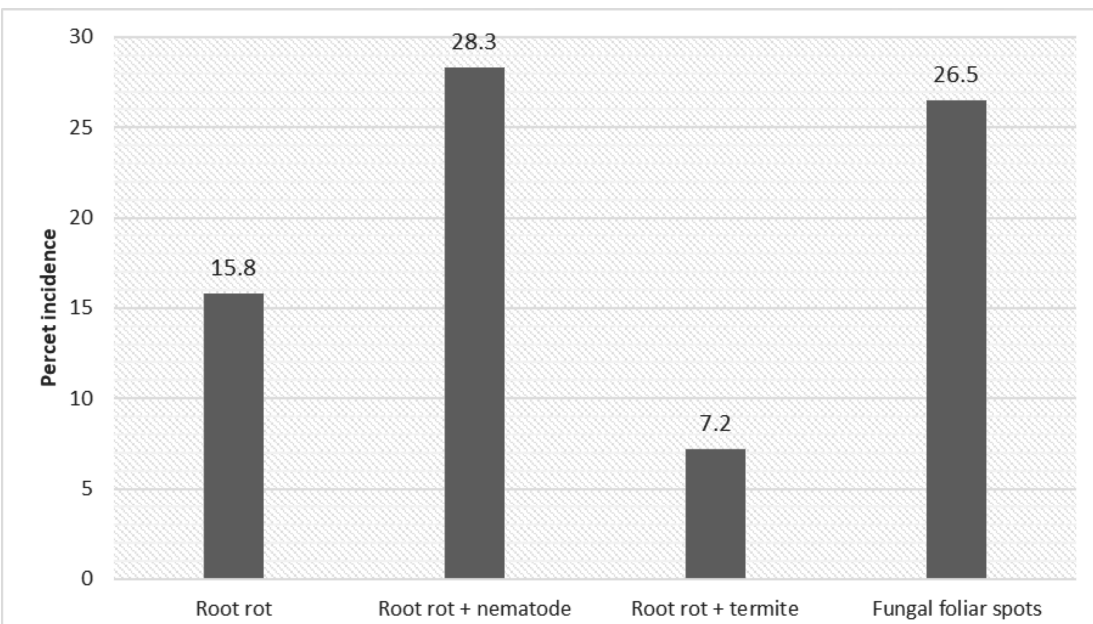

Fig. 1. Percentage of incidence of different problems resembling sudden wilt problem (2017-2018)

During 2018-19, survey data from farmer's fields indicated that 94.6 per cent of farmers have not done deep ploughing since last 5 years or more, 70 per cent of farmers were following cotton-wheat-cotton cropping system,

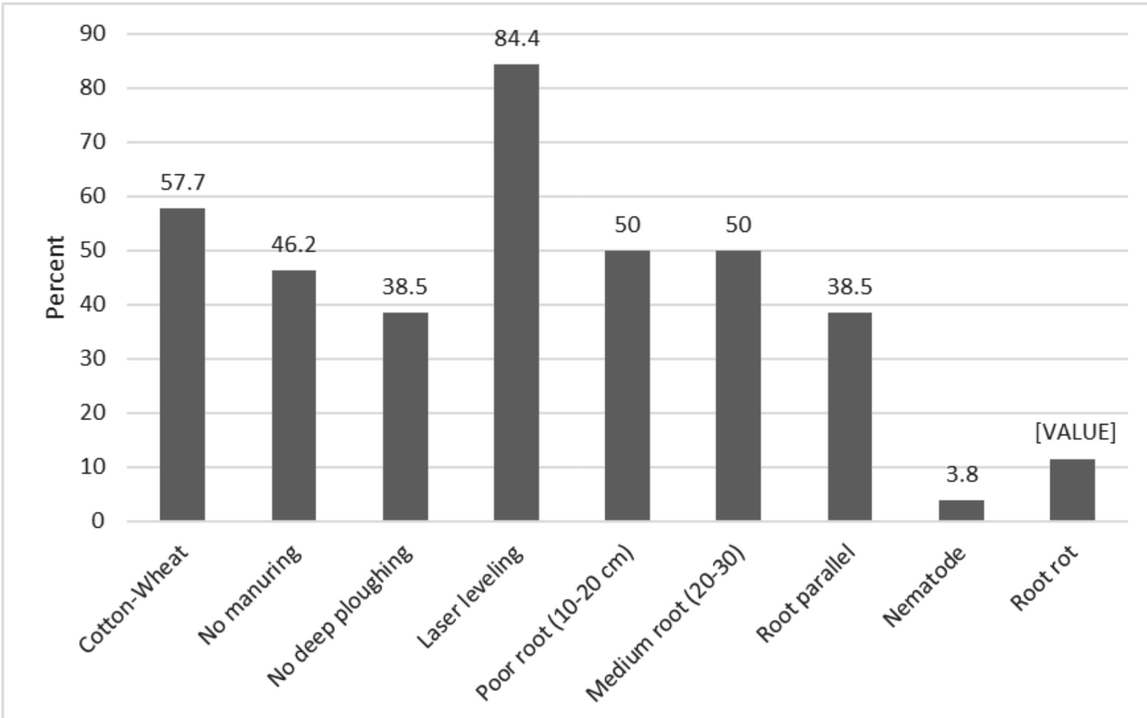

Fig. 2. Percentage of incidence of different problems resembling sudden wilt problem (2017-18)

48.6 per cent of farmers have applied the first irrigation before 30 days against the recommendation (45-50 days after sowing). Among these, 35.1 per cent farmers have followed all three practices- i.e. cotton-wheat-cotton cropping system, no deep ploughing and early irrigation. 20.7 per cent farmer's fields had the soil hard pan conditions, 11 per cent have followed cotton-mustard-cotton cropping system, 5.4 per cent fields were with high soil moisture nearer to paddy growing areas. Such field also had the biotic problems like root rot and nematode infection (32.4%), root rot (10.8%), root rot and termite (8.1%) and fungal foliar spots (24.3%), while 29.7 per cent cotton field were observed with the sudden wilting problem during the month of September onwards. Also, the sudden wilting situation was more prominent in early maturing and high yielding *Bt* hybrids during first fortnight of September. Out of all, only 10.8 per cent farmers fields (10.8 %) sudden wilting was not observed. In such fields, farmers have adopted crop rotations, crop residue incorporation, deep ploughing, timely irrigation etc. resulted better crop with deep rooted system (>30 cm) (Fig. 3).

Among the 29.7 per cent cotton fields observed with sudden wilting type problem, those fields were observed to be with no deep ploughing, cotton-wheat-cotton cropping system since past 5 years or more and early irrigation (before 30 DAS). The soil EC and pH in these fields were ranged between 2.5 to 4.5 dS/m and 7.6 to 7.9, respectively. These practices and soil health situations appeared to be the main reasons for parawilt/sudden wilt followed by enhanced vulnerability of cotton crop to biotic problems such as root rot; nematodes, fungal foliar spots

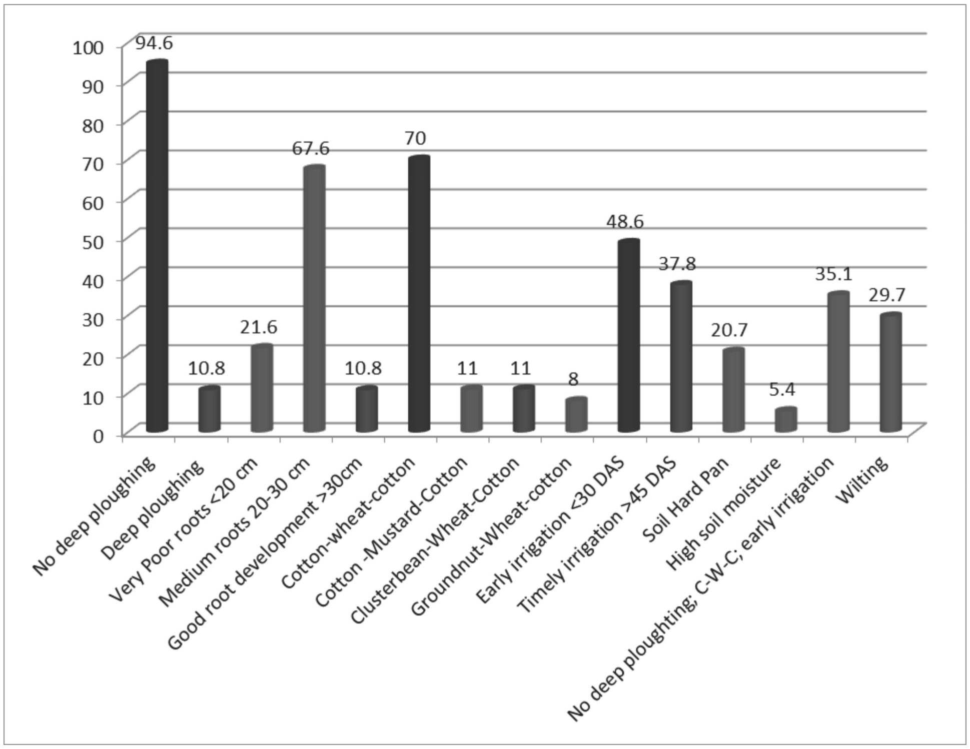

Fig. 3. Percentage of different cultural practices being followed by and the problems being faced by cotton farmers (2018-2019)

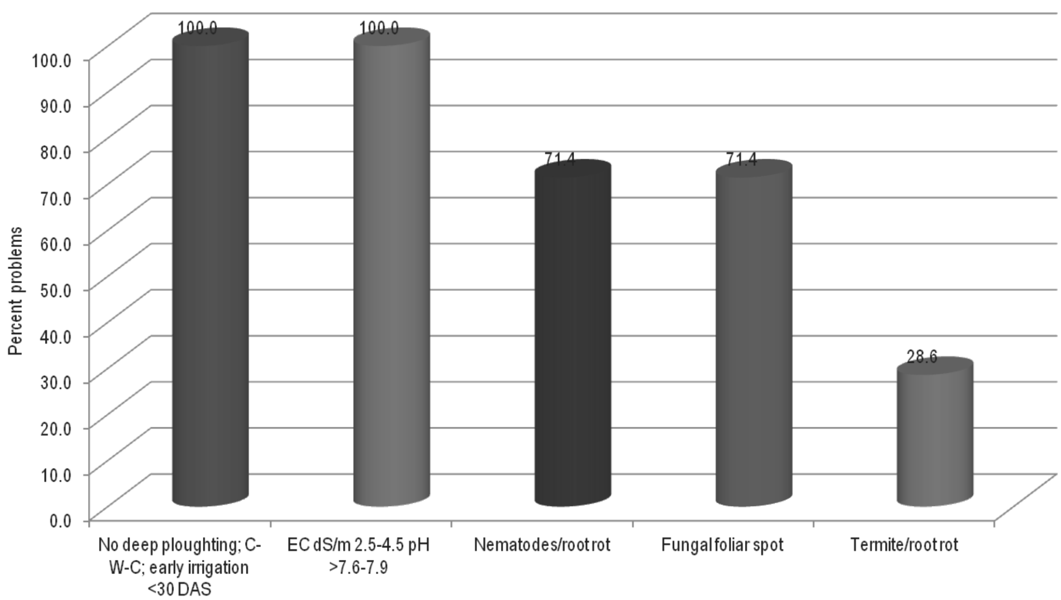

Fig. 4. Predominant factors found to be responsible for wilting in cotton fields

(71.4%), and termites/root rot (28.6%) (Fig. 4).

As, it is well understood that, the root growth in cotton (total root length) increases as the plant develops until fruiting begins (McMichael, 1986; Mai *et al.,* 2012). The total root length reaches a peak at peak plant height and reproductive growth commences *i.e.* onset of flowering. Although the nutrient and water requirements of cotton plants will be lower during advanced growth stages, it is still necessary to maintain relatively high root activity for normal boll opening and to achieve a high yield (Taylor and Klepper, 1974). The root length then begins to decline as plant height stays the same and older roots die. From 120 DAS to 160 DAS, the root length decreases in the 0–10 cm soil layer and decreased significantly in the 20–40 cm layer. The root length in 0–10 cm layer declines under flood irrigation from 125 to 160 DAS, but in 40–60 cm soil depth roots continue to grow, and thus the root system is able to compensate for the decline in root density in shallow soil layers (Mai *et al.,* 2012).

Cotton roots are more sensitive to increased soil strength than other crops (Taylor and Ratlife, 1969). The depth of penetration of main and lateral roots may vary according to the variety, soil type, soil water content, and other soil and plant related factors and conditions. In the present study, the root depth in the affected fields was ranged between 10-20 cm with higher root density in first 10 cm layer in 21-50 per cent fields and 20-30 cm root depth in 50-67.5 per cent fields. This may be due to continuous adoption of cotton-wheat-cotton cropping system, low organic carbon, and no deep ploughing which increases soil compactness. Moreover, the late sowing crops (after 15 May) face the raised soil temperature which may cause negative effect on proper root development. The optimum soil temperature for cotton root growth is somewhere between 28 °C and 35 °C (Taylor *et al.,* 1972). The overall rate of cotton root elongation is reduced, more branching will occur and enzymatic activity and metabolism is reduced at high temperature (Taylor 1983). The early and frequent irrigation (before 45 DAS) enhance more number of fine lateral root system during the early growth phase and ultimately reduced the main tap root system and this is more in shallow soils (Wei *et al.,* 2002; Bhattarai *et al.,* 2008). The roots of cotton are also sensitive to nitrogen stress and high nitrogen fertilizer reduces root length (in 0-40 cm layer), root surface area, volume, and diameter and stimulated the growth of the above-ground parts (Min *et al.,* 2014, Xu *et al.,* 2015). Consequently, the poor root development with decreased root depth during early stage may not be able to maintain the balance between uptake and the requirement of water and nutrients of the plant for its reproductive activities and leads to sudden wilting at their grand growth phase. Additionaly, the decline in cotton root length during advanced growth stages under shallow cultivated soils might also partly reflect local accumulation of salt (bore well water). Soil salinity is a dominated factor affecting cottons above-ground dry mass, root development and K uptake. The soil at the fields in North India have a naturally high salt content (EC 2.5 to 4.5 dS/m, pH 7.6 to 7.9) in 0-10 cm layer which may laso contribute in the reduction of water and nutrient uptake by the plants. The salt content of the tillage layer (0–30 cm) decreases because it is maintained in a moist state, but soil salt migrates and accumulates below the tillage layer (Malash *et al.,* 2008). Seed dry weight is reduced by 22, 52, and 84 per cent when the soil salinity level increased from control level of 2.4 dS m^{-1} to 7.7 dS m^{-1}, 12.5 dS m^{-1} and to 17.1 dS m^{-1}, respectively (Chen *et al.,* 2010). Both cellular and metabolic processes involved in osmotic stress due to salinity are similar to those due to drought (Tang *et al.,* 2007). More squares and bolls develop at later plant growth stage, greater quantities of nutrients and carbohydrates will be transported to the reproductive organs, whereas carbohydrate supply to the roots will be reduced. Together with increased root degradation by rhizosphere insects and parasites (Eissenstat *et al.,* 2000), the decline in root biomass would more rapid because of greater fine-root formation under early irrigation and or drip irrigation. The increased root degradation may also be one of the resion for increased virulence of the week plants for root rot, termite, and fungal foliar spots.

The use of cobalt chloride @10 ìg mL^{-1} in Punjab (Sarlach and Kaur, 2013) which is known to inhibit biosynthesis of ethylene (Lim and Yang, 1976). But, once the plants are affected with parawilt, cobalt chloride treatment is not showing much recovery in many fields. Also, ethylene production in the parawilt affected cotton plant did not have sufficient experimental proof to confirm that it could be the primary causative agent of parawilt in waterlogged areas (Hebbar and Mayee, 2011). However, the present study indicates that the crucial factors especially soil health management and cultural practices being adopted for development of root system coinciding with shoot growth, which can be the precursors (below ground interaction) of these later physiological conditions and biochemical changes. Moreover, long-term use frequent irrigation or early irrigation can cause negative impacts on development of root systems and reduction in taproot length and density of root growth in shallow soil layer. In the present study it was recorded, that development of root system is affected by cropping system, soil compaction, soil aeration, soil salinity, quality, time and frequency of irrigation water, cultural practices, fertilizer application etc. Lack of these practices results in poor root development (10-30 cm) and sudden wilt like problems and or increased other biotic problems. Late sowing (After mid May) coupled with early and frequent irrigation also results in poor root development (10-30cm) with higher density in 0-10 cm may cause imbalance between the uptake and loss of water and nutrients at 125-140 DAS. Moreover, heavy application of nitrogen fertilizers during early growth stage reduces root growth and enhances shoot growth. The early and frequent irrigation with saline water with poor soil aeration enhances the soil compaction which results in poor root growth, reduces tap root length and increases root density in upper soil layers (parallel roots).

In conclusion, it is essential to stimulate root development in deeper soil layers (40-60 cm) to maintain the vitality of the root system during advanced growth stages, and so that the nutrient and water needs of the shoots can be met. Well developed deep root system not only prevents reliance on absorption of nutrients and water from shallow soil layers, but at advanced growth stages and even under stressful conditions such as drought/saturation stress, low temperature and it will enable the plant to utilize nutrients and water in deep soil layers. Sudden wilt tolerant cotton cultivars have a positive association with root volume and depth, as it would get O_2 from larger areas (Hebbar and Mayee 2011). Moreover, the excessive shoot growth with excess application of N fertilizers also declines root systems; hence, carbohydrate allocation during early growth and development should be regulated to promote root growth. To achieve the development of a healthy root system, cultivation of cotton should focus on the following two aspects. First, a large and deep root system should be developed as quickly as possible and shoot growth should be controlled before the plants enter the reproductive growth stage. Site-specific management strategies need to be taken into consideration to optimize better crop health and yields. Furthermore, management strategies should be flexible to allow for changing environmental conditions.

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Efficacy of insecticides against sucking pests of cotton

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ABSTRACT : The field experiment was conducted during *kharif* 2015-16 in the research farm of the All India Coordinated Research Project on Cotton under the Regional Research and Technology Transfer Station (OUAT), Bhawanipatna situated in the Western Undulating Agro-climatic Zone of Odisha to study the efficacy of insecticides against sucking pests of cotton. The trial was laid out in randomized block design with eight treatments and three replications. The lowest population of jassids (1.19 / 3 leaves), aphids (2.17 / 3 leaves) and thrips (0.61 / 3 leaves) were recorded with Flonicamid (50% WG) @ 100 g a.i/ha followed by Flonicamid (50% WG) @ 75 g a.i/ha with jassids (1.83 / 3 leaves), aphids (2.47 / 3 leaves) and thrips (0.94 / 3 leaves) and Diafenthiuron (50% WP) @ 300 g a.i/ha with jassids (2.28 / 3 leaves), aphids (2.61 / 3 leaves) and thrips (0.94 / 3 leaves). Maximum seed cotton yield of 24.73 q/ha was recorded in Flonicamid (50% WG) @ 100 g a.i/ha which was statistically at par with Flonicamid (50% WG) @ 75 g a.i/ha with 23.79 q/ha, Diafenthiuron (50% WP) @ 300 g a.i/ha with 23.33 q/ha and Buprofezin 25%SC @ 250 g a.i/ha with 21.73 q/ha. Flonicamid (50% WG) @ 100 g a.i/ha recorded the highest B: C ratio (2.50) followed by Flonicamid (50% WG) @ 75 g a.i/ha with 2.47 and Buprofezin 25%SC @ 250g ai/ha with B:C ratio of 2.36.

Key words : Aphid, cotton, insecticides, jassids, thrips

Cotton is grown as a commercial crop in the western and southern parts of Odisha under upland rainfed condition. The crop occupied 1.58 lakh ha during the year 2018-19 with a production of 4.50 lakh bales of 170 kg and productivity of 484 kg lint/ha (Anonymous, 2018-2019). The productivity of cotton in the state is less as compared to the national average of 502 kg lint/ha and it is mainly due to the higher incidence of sucking pests. Further, with its extensive cultivation as a monoculture crop, it is attacked by many chewing and sucking insects (Saeed *et al.*, 2007). Among the sucking pests aphid (*Aphis gossypii* Glover), jassids (*Amrasca biguttula biguttula* Ishida), thrips (*Thrips tabaci* Lind.) and whitefly (*Bemisia tabaci* Genn.) are the major pests of cotton (Kadam *et al.*, 2014). These sucking pests are noticed at all the stages of crop growth and responsible for direct and indirect yield losses. A reduction of 22.85 per cent in seed cotton yield due to sucking pests had been reported by Satpute *et al.*, (1990). Regular and indiscriminate use of chemical insecticides and the misuse of synthetic pesticides on the crop have led to development of insecticide resistance in target pests, pest resurgence and secondary pest outbreaks, loss of bio-diversity, environmental pollution and residual toxicity and occurrence of human health hazards. However, in present day context chemical control has its own popularity over the other methods of pest control due to its immediate action and remarkable pest control. There is a scope of utilizing the newer molecules such as Pyridincarboxamide and Neonicotinoids which are required in small quantity and economically effective for control of sucking pests in cotton ecosystem. Also, the recent trends in pest management emphasises on nonchemical approaches and there is worldwide demand for organically grown fibre which is increasing annually in export markets. Keeping this point in view, the present study was carried out to evolve the efficacy of newer insecticides for the management of major sucking pests of hybrid cotton and to find out the most cost effective insecticide treatment.

MATERIALS AND METHODS

The experiment was conducted during *Kharif,* 2015-2016 in the research farm of the AICRP on Cotton under the Regional Research and Technology Transfer Station, Bhawanipatna in Kalahandi district of Odisha. The experiment was laid out in Randomized Block Design with 8 treatments (Table-1) and three replications. Insecticides treatments *viz.,* T_1: Buprofezin 25%SC @ 250 g a.i/ha, T_2: Flonicamid (50% WG) @ 75 g a.i/ha, T_3: Flonicamid (50% WG) @ 100 g a.i/ha, T_4: NSKE (5%) @ 5 ml/l, T_5: Diafenthiuron (50% WP) @ 300 g a.i/ha, T_6: *V. lacanii* @ 10 g/l, T_7: *M. anisopliae* @ 10 g/l and T_8: Control (unsprayed) were evaluated against sucking pests of cotton. The sowing was done by hand dibbling with untreated seeds of cotton hybrid DCH 32 by placing 2 seeds/mount with a spacing of 90 x 60 cm on 9th July 2015. Chemical fertilizer was applied @ 120:60:60 kg N, P_2O_5 and K_2O/ha. Gap filling was done within 5-10 days after emergence of the crop and thinning was carried out at 15 days after emergence of the crop keeping one healthy seedling/mount. Intercultural and weeding operations were carried out as needed. Three sprays of insecticides were applied, first spray was done at economic threshold level (ETL) of pests and subsequent sprays were given at 15 days interval. The observations on incidence of sucking pests like aphids, jassids and thrips were recorded by visual count from three leaves (each from top, middle and bottom) per plant on five randomly selected plants in each plot. The observations were recorded one day before spray and on 7th day after each spray. The plot yield in each treatment was recorded and expressed in q/ha.

The data recorded on sucking pest population from field experiments were subjected to square root transformation and data were analyzed following procedures laid out by Gomez and Gomez, 1984. The treatment variations were tested for significance by "F" test. The standard error of means SE(m) + and critical differences (CD) at 5% level of significance were calculated following the standard procedure and treatment means were compared using critical differences(CD). Based on the statistically analyzed data, the results of the investigation have been interpreted and conclusions have been drawn.

RESULTS AND DISCUSSION

The data presented in Table 1. revealed that jassids, aphids and thrips population varied from 6.75 – 7.33/3 leaves, 13.50 – 21.25/3 leaves and 7.67 – 8.58/3 leaves before first spray and all the treatments are statistically at par with each other. Significant differences were observed for population of sucking pests in cotton for different treatments under study.

After consecutive three sprays all treatments performed significantly better over the control. The lowest mean population of jassids (1.19 / 3 leaves) was recorded in T_3 (Flonicamid (50% WG) @ 100 g a.i/ha) and it was *at par* with T_2 (Flonicamid (50% WG) @ 75 g a.i/ha) with (1.83 / 3 leaves) and second lowest jassids mean population was recorded inT_5 (Diafenthiuron (50% WP) @ 300 g a.i/ha) with (2.28 / 3 leaves) as compared to the control (17.42/3 leaves) T_8. The present findings are in agreement with Chinna Babu Naik *et al.* (2017) who reported that Flonicamid 50 WG is very effective in managing cotton leaf hopper. Similar results were obtained by Kadam *et al.* (2014) and Kumar *et al.*, (2011) who observed that maximum mortality of jassids was found in flonicamid treated plot.

After three sprays the lowest mean aphids (2.17 / 3 leaves) population was recorded in T_3 (Flonicamid (50% WG) @ 100 g a.i/ha) which was at par with T_2 (Flonicamid (50% WG) @ 75 g a.i/ha) with 2.47 / 3 leaves and T_5 (Diafenthiuron (50% WP) @ 300 g a.i/ha) with 2.61/ 3 leaves as compared to the untreated control plot (24.75/3 leaves). The present results are comparable with the observations of Ghelani *et al.*, (2014) who reported that the treatments with flonicamid caused significantly maximum mortality of aphids. Gaurkhede *et al.* (2015) observed minimum aphid population in the plots treated with flonicamid 50 WG @ 0.02 per cent. According to Morita *et al.,* (2014) flonicamid wasa very active against wide range of aphid species and also effective against some other species of sucking insects.

The thrips population recorded during the study period was very low. Similar type of efficacy trend was observed in case of thrips, after three sprays the lowest mean population of thrips was recorded in Flonicamid (50% WG) @ 100 g a.i/ha with 0.61 thrips/ 3 leaves which was at par Flonicamid (50% WG) @ 75 g a.i/ha and Diafenthiuron (50% WP) @ 300 g a.i/ha with 0.94/ 3 leaves as compared to the untreated control with 10.03/3 leaves. These findings are in comfirmity with those obtained by Ghelani *et al.,* (2014) and Ravikumar *et al.,* (2016) who reported that maximum mortality of thrips with flonicamid 50WG application. Similar results were also documented by Meghana *et al.,* (2018), Sathyan *et al.,* (2016).

Data presented in Table 1. indicated that the maximum seed cotton yield of 24.73 q/ha was recorded in T_3 (Flonicamid (50% WG) @ 100 g a.i/ha) which was statistically at par with T_2 (Flonicamid (50% WG) @ 75 g a.i/ha) with 23.79 q/ha, T_5 (Diafenthiuron (50% WP) @ 300 g a.i/ha) with 23.33 q/ha and T_1 (Buprofezin 25%SC @ 250 g a.i/ha) with 21.73 q/ha. The increase in seed cotton yield in T_3 (Flonicamid (50% WG) @ 100 g a.i/ha) was 41.39 % over the control. Flonicamid (50% WG) @ 100 g a.i/ha (T_3) recorded the highest B: C ratio (2.50) followed by (T_2) Flonicamid (50% WG) @ 75 g a.i/ha (2.47).

Table 1. Effect of the different treatments on population of sucking pests and seed cotton yield

Treatments	Jassid/ 3 leaves		Aphids / 3 leaves		Thrips/ 3 leaves		Yield	B:C
	Before Spray	After Spray	Before Spray	After Spray	Before Spray	After Spray	(q/ha)	ratio
T_1: Buprofezin (25%SC) @ 250g ai/ha	7.33(2.80)	3.11(1.90)	20.67(4.59)	3.78(2.04	7.67(2.86)	1.69(1.46)	21.73	2.36
T_2: Flonicamid (50% WG) @ 75g ai/ha	6.92(2.72)	1.83(1.51)	18.75(4.39)	2.47(1.71)	8.25(2.96)	0.94(1.20)	23.79	2.47
T_3: Flonicamid (50% WG) @ 100g ai/ha	6.75(2.69)	1.19(1.28)	15.00(3.92)	2.17(1.62)	8.00(2.91)	0.61(1.04)	24.73	2.50
T_4: NSKE (5%)	7.08(2.75)	7.03(2.73)	21.25(4.65)	10.64(3.33)	8.25(2.95)	5.72(2.49)	20.99	2.27
T_5: Diafenthiuron (50% WP)@300g ai/ha	7.08(2.75)	2.28(1.64)	20.33(4.56)	2.61(1.75)	8.25(2.95)	0.94(1.19)	23.33	2.33
T_6: V.lacanii @ 10 g/l	6.83(2.70)	7.39(2.80)	13.50(3.71)	10.83(3.36)	8.58(3.01)	5.64(2.47)	19.60	1.99
T_7: M.anisopliae @ 10 g/l	7.00(2.74)	7.89(2.89)	19.42(4.46)	11.44(3.45)	8.58(3.01)	5.75(2.50)	20.82	2.12
T_8: Control	6.92(2.72)	17.42(4.20)	17.50(4.24)	24.75(5.02)	8.33(2.96)	10.03(3.24)	17.49	1.97
SE(m)	0.09	0.11	0.29	0.13	0.15	0.11	1.44	
CD(p=0.05)	0.20	0.24	0.61	0.29	0.32	0.24	3.08	
CV (%)	4.10	5.89	8.12	5.95	6.28	7.09	8.16	

CONCLUSION

It can be concluded from the experiment that sucking pests of cotton like aphids, jassids and thrips can be effectively and economically controlled with three sprays of Flonicamid (50% WG) @ 100 g a.i/ha or Flonicamid (50% WG) @ 75 g a.i/ha.

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YOUNG SCIENTIST ACADEMIC AWARD PAPERS

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Response of *Bt* cotton (*Gossypium hirsutum* L.) to seed treatment and foliar application of Nano zinc

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ABSTRACT : A field experiment was conducted at Main Agricultural Research Station, Dharwad, during 2017-2018 to evaluate the effect of seed treatment and foliar application of nano ZnO on growth, yield and economics of *Bt* cotton. The experiment was laid out in split plot design with three main treatments (M_1:seed treatment with chelated $ZnSO_4$@ 4 g /kg seeds, M_2: nano ZnO @ 1 g /kg seeds and M_3:seed priming with 1000 ppm nano zinc solution), four sub plot treatments (Foliar application of nano ZnO @ 500, 750, 1000 and 1250 ppm at square initiation and flowering stage) and three uneven control (C_1: RDF + FYM + 0.5 % EDTA $ZnSO_4$ foliar application at square initiation and flowering stage, C_2: C_1 + seed treatment with Fe, Zn, Mg and Mn @ 4g each /kg seed and C_3 : Only RDF + FYM @ 5.0 t /ha) treatments replicated thrice. Among seed treatments, higher seed cotton yield (2842 kg /ha), good opened bolls (62.2), boll weight (5.9 g) values were recorded with nano ZnO seed treatment than seed priming with nano zinc solution and chelated $ZnSO_4$ seed treatment. Among different foliar spray concentrations, foliar application of nano ZnO @ 1000 ppm recorded higher seed cotton yield (2718 kg /ha), total zinc uptake (196.1 g /ha) and fibre strength (31.4 g/tex) than other concentrations. Among all treatment combinations, seed treatment with nano ZnO in combination with foliar application of nano ZnO @ 1000 ppm recorded significantly higher seed cotton yield (3221 kg /ha), total dry matter production (473.0 g/plant) than recommended practices. The SEM images revealed the complete absorption of nano zinc oxide by leaves. The SEM images shows the presence of nano particles and the EDX analysis revealed the presence basic elements like carbon and oxygen. Primary elements like N, P and K were a higher in 1250 ppm than other lower concentrations (3.86, 0.95 and 3.97 at square initiation stage and 34.28, 1.51 and 3.78 at flowering stage, respectively). The bioaccumulation of elements increased with increasing concentration of ZnO nanoparticles when sprayed on foliage and is evident that the penetration of this nano fertilizer was effective to reach through stomatal pores.

Key words **:** Cotton, foliar application, micronutrient, nano zinc oxide

Cotton, the white gold, is the world's leading fibre crop and the second most important oilseed crop. Cotton production, processing and trade provide livelihood and employment to several millions of people. Cotton is a tropical and subtropical crop.

Apart from major nutrients, micronutrients also play a vital role in cotton production.Zinc is an essential micronutrient for human, animal and plants. Plants absorbs Zn in the form of Zn^{+2}. Zinc is immobile in the soil and needs to be either mixed through the root zone or sprayed on to the leaf to supply plant available zinc. This can be done through incorporation of surface applied zinc, in furrow injection or a foliar spray.

Emphasis on present day agriculture is to produce more with lesser land, water and man power. Considering the above factors with a growing world population there has been a growing interest to develop such management practices or tools which alone or in combination with other practices could ensure a good yield. For this seed treatment and foliar application with micronutrients are the major tools

Due to the significance of zinc element in crop growth and production and their positive role in increasing yield and quality due to application of nano form through seed treatment and foliar spray in cotton. the time and speed for the release of elements coincide and match plant nutritional requirements, thus the plant can absorb maximum amount of nutritional elements and, as a consequence, the product yield increases as well.

However, The studies related to seed treatment and foliar application of nano ZnO on cotton in India is very meager or seldom nil. Hence the present investigation was carried out to know the impact of seed treatment and foliar application of nano Zinc fertilisers on yield and quality parameters in *Bt* cotton.

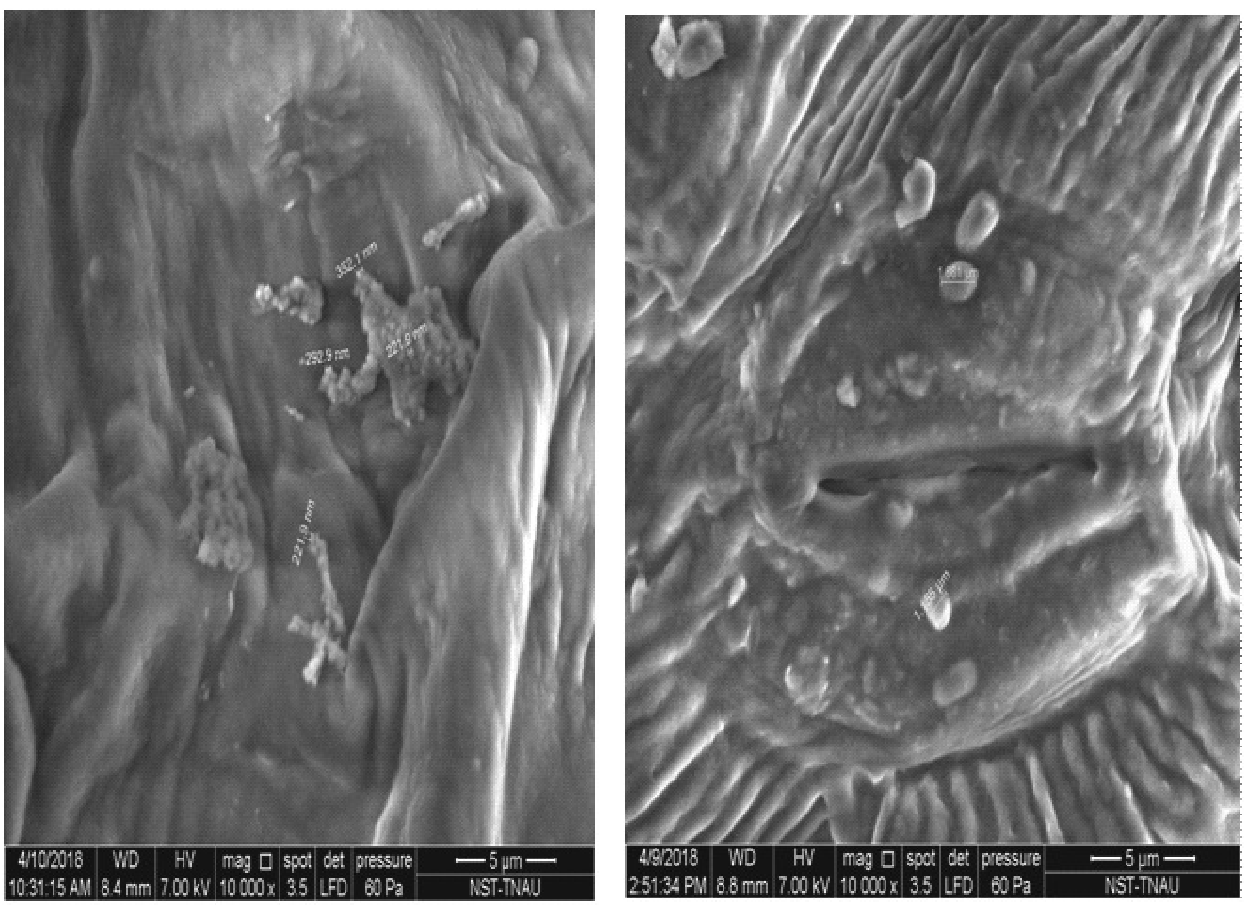
MATERIALS AND METHODS

A field experiment was conducted at Main Agricultural Research Station, Dharwad during *kharif* 2017-2018. The experiment was laid out in split plot design with three main treatments (S_1: seed treatment with chelated $ZnSO_4$ @ 4 g /kg seeds, S_2: nano ZnO @ 1 g /kg seeds and S_3: seed priming with 1000 ppm nano zinc solution), four sub plot treatments (Foliar application of nano ZnO @ 500, 750, 1000 and 1250 ppm at square initiation and flowering stage) and three uneven control (C_1: RDF + FYM + 0.5 % EDTA $ZnSO_4$ foliar application at square initiation and flowering stage, C_2: C_1 + seed treatment with micronutrients Fe, Zn, Mg and Mn @ 4g each /kg seed and C_3 : RDF + FYM @ 5.0 t /ha) treatments replicated thrice. The hybrid *Bt* Cotton Superb SP7157 (BG-II) was sown in a plot size of 7.2 × 5.4 m for each treatment. Seeds were dibbled as per the specification on 05th July 2017. Two seeds/hill were dibbled to a depth of 5 cm on flat bed in 90 cm rows at 60 cm distance between plant to plant and recommended dose of fertilizers (RDF) @ 100:50:50 kg N: P_2O_5 : K_2O /ha + FYM @ 5.0t/ha was applied commonly to all treatments.

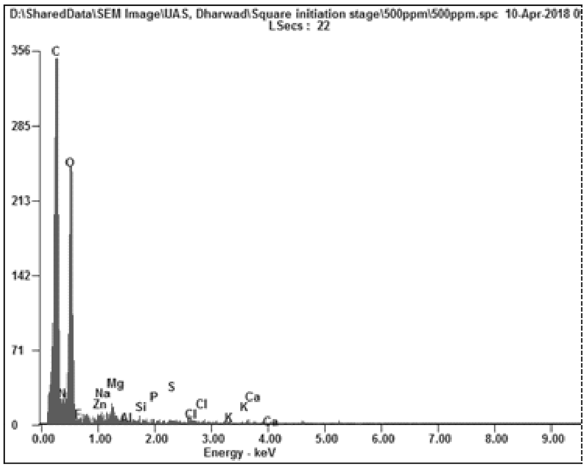
Interaction effect of seed treatment and foliar application of nano zinc : Interaction effect of seed treatment and foliar application of nano zinc resulted in significant effect on yield, yield attributing characters and nutrient uptake.

In the present investigation, different foliar spray concentration with chelated $ZnSO_4$ seed treatment, did not affect seed cotton yield significantly, similar trend was followed for all growth and yield attributing characters except number of bad opened bolls. Bad opened bolls were higher with 500 ppm foliar spray. Nano coating of seeds using elemental forms of Zn, Mn and Ag will not only protect seeds but also provided immune power to resist for drought and some extent to pathogens. Higher concentration of nano ZnO reduced the bad opened bolls. Seed treatment with nano ZnO recorded higher seed cotton yield with 1000 ppm foliar spray (3221 kg /ha). Similar trend was followed in all growth and yield attributing characters. But at 1250 ppm concentration, yield was reduced due to scorching effect in cotton plantsreported the scorching effect in sunflower crop @750 ppm nano ZnO foliar spray. also recorded similar observations in tomato @ 600 ppm concentration. For seed priming of nano ZnO with foliar spray of nano ZnO at different concentrations did not influence yield of cotton.

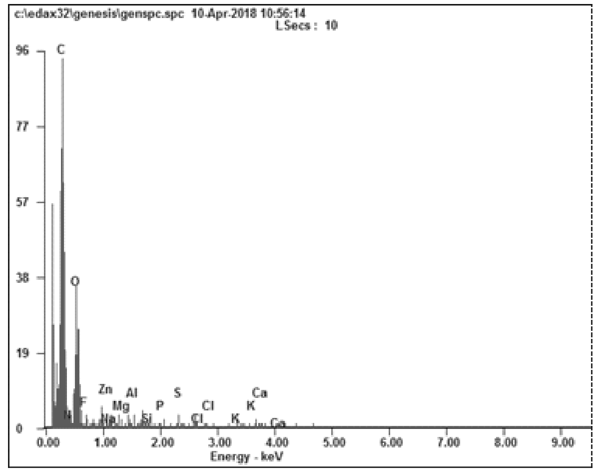
Nano particles uptake was confirmed by scanning electron microscope (SEM) and Energy Dispersive X-Ray (EDX). The nanoparticles as fertilizers potentially beneûts uptake system , they have showed better catalytic ability with increased surface area. They are highly dispersible and have high water adsorbing properties. Therefore, nano fertilizers can increase the efûciency of nutrient uptake which can improve yield and nutrient content in the edible parts of the plants. Exogenous application of nano ZnO in soybean and Brassica showed



Scanning electron microscope images (SEM) of *Bt* cotton leaf with foliar application ofnano ZnO @ 500 ppm.



Square initiation



Flowering stage

Energy dispersive X - ray (EDX) showing proportion of essential elements and functional nutrients in Bt cotton leaf with foliar application nano ZnO

improved Zn uptake with better growth and higher yield. Under moisture stress conditions uptake of Zn is limited due to the down regulation of many transporters. From this context the ZnO nano could provide an option to improve uptake of Zn under drought conditions.

Analysis of leaf samples of cotton by scanning electron microscope (SEM) and energy dispersive X-Ray (EDX) : In the present investigation, the results showed that ZnO nano particles could enhance the nutrient uptake and maintain the growth of cotton plants. The SEM images revealed the complete absorption of nano zinc oxide by leaves. The cotton leaf samples were collected 24 h after foliar application and subjected for SEM and EDX. The SEM images shows the presence of nano particles and the EDX analysis revealed the presence basic elements like carbon and oxygen, these elements were higher in 500 ppm foliar spray of nano ZnO (60.31 and 29.47 at square initiation stage and 44.66 and 55.94 at flowering stage, respectively), but decreased with increasing concentration from 500 to 1250 ppm foliar spray. Similarly per cent atomic weight of C and O. Further, primary elements like N, P and K were a higher in 1250 ppm than other lower concentrations (3.86, 0.95 and 3.97 at square initiation stage and 34.28, 1.51 and 3.78 at flowering stage, respectively). Similarly per cent atomic weight of primary nutrient elements were also higher at higher foliar spray concentration, Secondary elements like Ca, Mg and S were also influenced by nano ZnO foliar spray found to be higher at 1250 ppm (10.74, 1.81 and 1.15 at square initiation stage and 22.96, 2.99 and 2.91 at flowering stage, respectively) than other concentrations. Further, the per cent weight and atomic per cent of micro elements like, Fe, Zn and Cl were also higher with higher concentration of foliar application of nano ZnO (1250 ppm) than lower concentrations. The micro nutrient elements were lower at lower concentration of spray. The nano ZnO foliar application also influenced functional nutrient

Table 1. Bolls, Boll weight, Yield, and other parameters of *Bt* cotton as influenced by Nano ZnO seed treatment and foliar application

Treatments	Good opened bolls (GOB)	Bad opened bolls (BOB)	Total number of bolls	Boll weight (g)	Seed cotton yield (kg/ha)	Total zinc uptake (g/ha)	Fibre strength (g/tex)
S_1 : Chelated $ZnSO_4$(4 g/kg seeds in 8 ml polymer)	53.7	3.6	57.3	5.5	2309	188.2	31.1
S_2 : Nano ZnO (1 g/kg seeds in 8 ml polymer)	62.2	2.5	64.7	5.9	2842	198.4	31.5
S_3 : Nano Zinc 1000 ppm of 8 hours soaking (Seed priming)	57.4	2.7	60.1	5.6	2478	191.4	31.2
S.Em±	**0.71**	**0.14**	**0.95**	**0.05**	**39.5**	**0.32**	**0.02**
C.D. (p=0.05)	**2.13**	**0.42**	**2.85**	**0.15**	**155.2**	**0.96**	**0.06**
Sub plots: Foliar application of Nano ZnO. (F)							
F_1 : 500 ppm at square initiation and flowering stage	56.3	3.5	59.8	5.5	2381	189.5	31.1
F_2 : 750 ppm at square initiation and flowering stage	57.0	3.1	60.1	5.6	2528	192.3	31.2
F_3 : 1000 ppm at square initiation and flowering stage	59.0	2.8	61.8	5.8	2718	196.1	31.4
F_4 : 1250 ppm at square initiation and flowering stage	58.7	2.4	61.1	5.7	2545	192.8	31.3
S.Em±	**0.42**	**0.12**	**0.45**	**0.03**	**36.8**	**0.27**	**0.01**
C.D. (p=0.05)	**1.26**	**0.36**	**1.35**	**0.09**	**135.9**	**0.81**	**0.03**
Interaction: (SXF)							
S_1X F_1:	51.9	4.2	56.0	5.2	2284	187.2	30.8
S_1X F_2:	52.5	3.4	55.8	5.4	2292	187.8	31.0
S_1X F_3:	54.0	3.3	57.3	5.5	2310	188.4	31.1
S_1X F_4:	56.3	3.7	60.0	5.7	2349	189.5	31.3
S_2X F_1:	60.8	3.2	64.0	5.8	2558	193.1	31.4
S_2 X F_2:	61.7	2.9	64.7	5.8	2705	195.8	31.4
S_2 X F_3:	65.1	2.4	67.5	6.3	3221	205.9	31.9
S_2 X F_4:	61.0	1.6	62.7	5.8	2882	198.6	31.4
S_3 X F_1:	56.3	3.2	59.5	5.5	2301	188.3	31.1
S_3 X F_2:	56.8	3.0	59.8	5.6	2587	193.1	31.2
S_3 X F_3:	57.8	2.7	60.6	5.6	2623	193.9	31.2
S_3 X F_4:	58.7	1.9	60.6	5.7	2403	190.4	31.3
S.Em±	**0.72**	**0.15**	**0.82**	**0.06**	**91.2**	**0.33**	**0.03**
C.D. (p=0.05)	**2.16**	**0.45**	**2.46**	**0.18**	**276.9**	**0.99**	**0.09**
Control plots: (C)							
C_1 : RDF + FYM + 0.5 per cent EDTA $ZnSO_4$	50.2	8.3	58.5	4.6	1997	173.8	28.5
C_2 : (C_1 + seed treatment with micronutrients)	51.1	7.1	58.2	5.1	2097	175.5	29.3
C_3 :RDF only	49.7	9.7	59.4	4.7	1935	171.9	26.7
S.Em±	**1.1**	**0.3**	**1.2**	**0.2**	**102.4**	**5.5**	**0.2**
C.D. (p=0.05)	**3.3**	**0.9**	**3.7**	**0.6**	**296.7**	**15.9**	**0.6**

elements like Na and Si, they were also higher at higher concentrations. This clearly supported the fact that nano formulations were effective in reaching inner surface of leaf and enhanced the dry matter of photosynthesis surfaces. The bioaccumulation of elements increased with increasing concentration of ZnO nanoparticles when sprayed on foliage and is evident that the penetration of this nano fertilizer was effective to reach through stomatal pores. The size of stomatal pores generally range from few nanometers to 30µm in different crops.opined that the formulations prepared at nano scale and sprayed on foliage might have effectively deposited on leaf surface and have made their entry into the leaf pores. Therefore nanoparticles are more efficient than conventional fertilizers.

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Effect of sewage sludge and inorganic fertilizers on productivity and fertility of soil under cotton-wheat cropping system

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Cotton (*Gossypium hirsutum* L.)–wheat (*Triticum aestivum* L.) in the Indian sub-continent particularly in north-western plains of India (Punjab, Haryana and northern Rajasthan) is a fairly well-established cropping system since the last 50 years and it is highly remunerative for the generation of assured income and thus ensures food and financial security of farmers in this region.

This cropping sequence has high requirements for nutrients and may adversely affect soil fertility in long run if adequate management options are not adopted. As in modern agriculture, no single source of plant nutrients can sustain the soil productivity rather they need to be used in a coherent manner following a management technology that is economically profitable and ecologically sound. In order to sustain the agriculture and soil fruitfulness, organic fertilizers and various other organic materials got importance for enhancing the soil carbon stock and improving soil physico-chemical and biological conditions. Because of the positive effects of organic manures and the same time ever increasing cost of chemical fertilizers and their limited availability, the combined use of organic manures and chemical fertilizers is again regaining importance in crop production as well as for maintenance of soil productivity. In this respect, the use of treated sewage sludge as an organic source is an imperative tool that is of increasing interest of farmers and governmental bodies due to its over production and higher nutrient content. The fertilizer requirements of both the crops on an individual basis have already been worked out and well documented. There is a general tendency that both the crops in sequence receive their recommended fertilizer doses regardless of the fact that whether the previous crop has received the fertilizer or not. Still, the use of chemical fertilizers is the fastest way of counteracting the pace of nutrient depletion. The integration of mineral fertilizer and organic amendments such as sewage sludge proved a viable alternative for the cotton-wheat system across the northern India. Notwithstanding the numerous benefits of sewage sludge, its application is ignored by the farmers. Recognizing its potential, we need to give attention on the need for promoting the use of sewage sludge along with synthetic fertilizers in crops to derive maximum benefits and investment on research for initiating its use in crop production technologies. Therefore, keeping all the above discussed points in view, the present investigation has been planned and executed at Research Farm of Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana with the following objectives:

1. To study the effect of sewage sludge and chemical fertilizers on yield and nutrient uptake by the cotton-wheat cropping system.
2. To study the effect of sewage sludge and chemical fertilizers on soil properties.

A research trial on **"Effect of sewage sludge and inorganic fertilizers on productivity and fertility of soil under cotton-wheat cropping system"** was initiated in the year 2015-2016 at Research Farm, Department of Soil Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India). The experimental soil was sandy loam in texture and of alkaline pH, medium in organic carbon content, low in available N and medium in available P and K respectively. The experiment was laid out in a split plot design with three replications. During three experimental years, the following treatments were applied to main-plots viz. SS (Sewage sludge)@ 5 t/ha, SS+N+50 per cent P, SS+N+75per cent P, SS+N+100per cent P, Recommended dose of N andP (RDNP). After the harvesting of wheat, main-plots were divided into sub-plots and then following treatments were applied viz. N+75per cent PK , NK+75per cent P , NP+75per cent K, NPK to the cotton crop. The salient findings of the experiment after completion of three years (2017-18) are summarized as follows:

1. The treatment SS + N + 100 per cent P followed by NPK application in the next crop recorded significantly higher wheat grain (5220 kg/ha) and straw yield (9906 kg/ha) of wheat as compared to 50 and 75 percent of RD of P along with SS + N and also higher with that of SS and NP when applied alone. Similar trend was observed in next crop of cotton grown in the same plots giving 4070 and 5427 kg/ha seed cotton and stover yield, respectively. From this trend, it can be said that 25per cent of RD P can be saved with the application of SS @ 5 t/ha.
2. Total uptake of NPK (301, 40, and 291 kg/ha, respectively) in wheat was highest with treatment combination of SS + N + 100 per cent P and RD NPK. The N and P uptake was higher in grain while K uptake was higher in straw.
3. In cotton, the total uptake of N (293 kg/ha), P (37 kg/ha) and K (174 kg/ha) were highest in different treatment combination i.e. SS + N + 100per cent P x N + 75per cent PK, SS + N + 100per cent P x NP + 75per cent K and SS + N + 100per cent P x RDNPK . The N uptake follows the trends: stem > seed > leaves > khokari. The P uptake follows the trends: seed > stem > khokri > leaves. Similarly K uptake follows the trends: stem > seed > khokri > leaves.
4. The highest micronutrients (Fe, Mn, Zn, Cu) uptake was observed in SS + N + 100 per cent P x NPK treatments in wheat and similar trend was observed in next crop cotton. The decreasing order of Fe, Zn and Cu uptake by different parts of cotton was seed > stem > leaves > khokri whereas in Mn, it was stem > leaves > khokri > seed.
5. The highest heavy metals content (Pb,

Cd, Cr, Ni and Co) in wheat grain and straw was reported with the application of SS +N + 100per cent P x N + 75per cent PK treatments.. The heavy metal content in wheat grain and straw follows the order Pb > Ni > Co > Cd > Cr. All the heavy metals content in grain and straw were below their permissible limits.

6. The highest heavy metals content (Pb, Cd, Ni and Co) in different parts of cotton was reported with the application of SS +N + 100per cent P x N + 75per cent PK treatment, except Cr. The highest content of Pb and Cd was observed in stem, Cr in seed, Co in leaves and Ni in khokri. All the heavy metals content were below the permissible limits.

7. The pH of soil slightly decreased from its initial value i.e. 8.2 to 7.93 while EC slightly increased form its initial value i.e, 0.21 dS m^{-1} to 0.28 dS m^{-1} because of high soluble salts in SS.

8. The organic carbon content of soil increases from its initial value of 0.42per cent to 0.49per cent with the application of sewage sludge and highest organic carbon build-up was observed in treatment SS + N + 100 per cent P x RD NPK.

9. The soil available N was decreased from its initial value (146 kg/ha) and found maximum in the treatment combination of SS + N + 50 per cent P x N + 75per cent PK treatment i.e. 150.2 kg/ha. The available P increased from its initial value (21 kg/ha)was reported highest (28.3 kg/ha) in SS + N + 100 per cent P x NP + 75per cent K. Integrated use of SS + N + 100 per cent P x RD NPK showed highest soil available K (229 kg/ha) which maintained close to its initial value.

10. The DTPA extractable micronutrients (Fe, Mn, Zn and Cu) in soil after harvesting of the crop significantly increased from their initial values (3.80, 8.00, 1.70 and 1.02 mg kg^{-1}), respectively with the application of SS as compared to the application of chemical fertilizers alone.

11. Application of SS increased the DTPA extractable heavy metal in soil. However, their concentration was below the permissible limit of heavy metal.

12. The MBC of soil differ non-significantly between SS and chemical fertilizer treatment. However, their highest value was observed in RD NP x NPK level of interaction.

It may be concluded from the study that SS + N + 100 per cent P followed by RD NPK in next crop, gave highest yield of wheat and cotton crop. The wheat grain and seed cotton yield was about 8.3per cent and 9.4per cent higher than that of RD NP and NPK, respectively. The nutrient content was also highest in the similar treatment. The SS application increased the P, K, OC, and micronutrient content in soil over their initial values. The micronutrient and heavy metal content was found under permissible limits in both soil and plant. Hence, sewage sludge (SS) collected from Hisar city can be used successfully under cotton-wheat cropping system for achieving higher yield and improving soil fertility.

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Yield, nutrients uptake and post-harvest available nutrients in soil by integrated nutrient management practices

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ABSTRACT : T_6(75 % RDN + 3 foliar spray of 2.5 % urea) gave highest seed cotton yield. This increased in yield due to increase in boll/ plants and boll weight due to the foliar application of urea. Treatment T_6 also gave higher yield than T_5(75 %RDN + *Azotobacter* + 3 foliar spray of 2.5 % urea) because of higher bolls/ plants. The available NPK status of soil decreased at harvesting as compared to its earlier growth stages.

Keywords : Bio fertilizer, chemical fertilizer, cotton, integrated nutrient management, growth, yield

Cotton is one of the world's leading agriculture crops. It is the most widespread profitable non-food crop in the world. It is considered as "King of fibers" and being important cash crop of the world. Cotton originated in the old world and was probably domesticated around 3000 B.C. (Eshanna, 2006). It is a soft, fluffy staple fiber that grows in a boll, or protective case, around the seeds of the cotton plant. It is a multipurpose crop that produces lint (fibre), oil, seed meal and hulls. Accounting for 11.91 per cent production and 6.77 per cent of hectare, Haryana is the fifth largest producer of cotton in India. In the year 2017-2018, Haryana produced 25 lakh bales. The state has the second highest yield of 6.48 q/ha in the country next only to that of the neighboring Punjab (Annual Report 2017-2018-ICAR). Cotton plant being a heavy feeder, needs proper supply of plant nutrients for its successive cultivation (Tayade and Dhoble, 2010). The maximum yield potential of *Bt* cotton hybrid can only be achieved with suitable agronomic practices like plant geometry and optimum fertilization over the years (Devraj *et al.,* 2011).To cater the uptake needs of this crop, soil reserves alone are not sufficient, hence needs to supply them through chemical fertilizers.Amongplant nutrients, N plays key role in crop productivity and it is regarded as growth and yield determinant in irrigated cotton (Ahmad *et al.,* 2000) Low efficiency of nitrogen applied to soil is a major problem to farmers. Nitrogen was subject to leaching, denitrification and volatilization losses, which made it unavailable to crop (Indal *et al.,* 2014, Byale *et al.,* 2017). Therefore, it is essential to introduce such fertilizer practices as would ensure maximum efficiency of applied nitrogen and these relate to placement, split application, appropriate rates and use of nitrification inhibitor for *Bt* cotton (Hallikeri *et al.,* 2010). Keeping in view, the experiment was planned to study the effect of integrated nutrient management in *Bt* cotton for sustaining yield, uptake and fertility status of soil.

The field experiment was designed and conducted on experimental Farm of Krishi Vigyan Kendra, Sirsa during *kharif* season with objectives to study the effect of different nutrient management practices on seed cotton yield and nutrient uptake by Bt cotton, fertility status of the soil and economic analysis of cotton production.

MATERIALS AND METHODS

The physio-chemical properties of experimental area was analysed and recommended dose of fertilizer was prepared. The experiment soil was sandy loam in texture and alkaline pH, medium in organic carbon content, low in available N and medium in available P and K, respectively. The experiment was laid out in a randomized block design (RBD) with following treatments *i.e.* T_1- Control, T_2- RDF on soil test basis (N in three split doses at basal, 45 and 75 DAS), T_3- RDN + *Azotobacter*, T_4- (75 %)RDN + *Azotobacter*, T_5- (75 %)RDN + *Azotobacter*+ 3 foliar spray of 2.5 % urea, T_6- (75 %)RDN + 3 foliar spray of 2.5 % urea, T_7- 100 % RDN in four split doses @sowing, 45, 75, 100 DAS and T_8- (75 %) RDN in four split doses @sowing, 45, 75, 100 DAS + 3 foliar spray of (2.5%) urea. The treatment were replicated thrice in a net plot area of 6 x 5 m. Recommended dose of fertilizers and other package of practices were uniformly adopted in all the treatments for growing healthy crop. All foliar sprays were applied from flowering to peak boll formation stage at 10 days interval.Recommended dose of P, K and other package of practices were uniformly adopted as per university recommendations.

RESULTS AND DISCUSSION

The seed cotton yield was significantly affected with different nutrient treatment and highest (2948.89 kg/ha) was in T_6 (75 %RDN + 3 foliar spray of 2.5 % urea) which was statistically *at par* with all other treatments.Treatment T_8 (75 % RDN in four split doses @sowing, 45, 75, 100 DAS + 3 foliar spray of 2.5 % urea) gave significantly higher seed cotton yield as compare to T_7 (100 % RDN in four split doses @sowing, 45, 75, 100 DAS) in which dose of N is reduced to 25 % and foliar application of urea is added. Also, T_7 gave higher yield than T_2 in which full N was applied in three split doses.The bolls/plant and boll weight was significantly affected by different nutrient management practices and was highest in T_6 (49.33 and 4.06 g, respectively). The dry weight of leaves increase from square formation stage to flowering and the decreases as the plant moves towards maturity whereas the dry weight of stem was increased continuously throughout the crop growth period.The dry weight of seed showed an increasing trend from 50 per cent boll opening to harvesting because of more translocation of nutrients and photosynthates. At square formation and flowering highest dry matter was found in T_3 (RDN + *Azotobacter*) while at 50 % boll opening highest dry matter was in T_2 (RDF on soil test basis (N in three split doses at basal, 45 and 75 DAS)) and at harvesting highest was in T_6(75 % RDN + 3 foliar spray of 2.5 % urea).Treatment T_6 gave highest nutrient content and uptake at the time of harvesting. The NPK uptake increased from square formation stage to harvesting stage. The nutrient content showed a decreasing trend in plant straw while it increased in seed. This was because of the foliar application of urea on leafs which translocate more nutrients to seed.The organic carbon of soil increases from its initial value up to square formation stage and then decreases continuously as plant move towards maturity. The organic carbon differs non-significantly with in treatments and reached near to its initial value. The available N increased from its initial value and then decreases. It vary significantly with in treatments and was highest in T_3 (RDN + *Azotobacter*). Treatment T_5 (75 %RDN + *Azotobacter* + 3 foliar spray of 2.5 % urea) gave higher available N as compared to T_6 (75 % RDN + 3 foliar spray of 2.5 % urea) because of *Azotobacter* which fix atmospheric N and provide it to plant. The available P was increased from its initial value up to square formation and then decrease continuously as plant reached towards maturity and highest was in T_4 (75 %RDN + *Azotobacter*). Similarly, available K increased from its initial value and then decreases and highest available K was in T_3 (RDN + *Azotobacter*).Highest net return and B: C of Rs. 68,214/ ha and 1.84, respectively was obtained in T_6 while the lowest was in control.

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High density planting is viable alternative for rainfed cotton production

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ABSTRACT: A field experiment was conducted during the year 2018 – 2019 on clay soils of Regional Agricultural Research Station Lam, Guntur, to study "Standardization of crop geometry and nitrogen levels for compact cotton genotype (*Gossypiumhirsutum* L.) in rainfed vertisols" on compact cotton variety LHDP 1. The experiment was laid out in a randomized block design with factorial concept with treatments consisted of three crop geometries S_1 - 60 × 10cm, S_2- 75 × 10cm, S_3- 90× 45cm in combination with four nitrogen levels N_1- 45kg N/ha, N_2- 90kg N/ha, N_3- 135kg N/ha, N_4- 180kg N/ha with three replications. Results indicated that seed cotton yield (4567kg/ha), gross return (Rs. 2,42,060/ha), net returns(Rs.1,68,904/ha) and return/rupee investment(2.31) were recorded maximum with closer crop geometry of 60 × 10cm over other crop geometriesy tested. The maximum seed cotton yield (3990kg/ha), gross returns(Rs.2,11,475/ha), net returns (Rs.1,45,085/ha) and return/rupee investment (2.2) was recorded with application of 135kg N/ha than other nitrogen levels tested.

Keywords *:* Crop geometry, high density planting system, return/rupee investment, seed cotton yield

Cotton (*Gossypium hirsutum* L.) is the most important fibre as well as commercial crop of India and AndhraPradesh. It presumes importance in agriculture as well as in Industrial economy. Cotton occupies a major share among cash crops as it supports the large section of farming community as well as it provides raw material to textile industries. Commercially, cotton is the best export earning commodity in the country. Hence it is known as **"White Gold".** In India cotton occupies first rank in area (122.38 lakh ha) and have~~ing~~ second position in production (361 lakh bales). However, i~~I~~n India, the seed cotton yield/unit area (501kg lint/ha) is still far below than many other cotton growing countries in the world. (AICCIP, Annual report, 2018 - 2019). In India , about 65 per cent cotton is cultivated ining rainfed condition. Among the various factors responsible for low yield of cotton low plant population and use of low potential varieties are of primary importance. Various agronomic interventions like maintaining suitable plant densities, use of optimum dose of fertilizers, growth regulators etc are being used to overcome these curtailments in cotton production.

High density planting system (HDPS) is now being considered as an alternate production system having a potential for improving the productivity and profitability of cotton. Increasing input use efficiency, reducing input costs and minimizing the risks associated with current cotton production system in India is the main objectives of high density planting system (Venugopalan *et al.,* 2014).

In countries such as USA, Australia and Brazil, cotton is grown on larger, modernized farms using mechanized technology. In India, it is in small scale with labour intensive production like hand weeding and picking and becoming expensive day by day. At present, in India, entire cotton is picked manually. Machine picking is a viable alternative to manual picking. Mechanization not only alleviates labour shortage, minimize cost of cultivation, but also enhances productivity by efficient and uniform utilization of inputs and by saving time. Mechanization cotton is possible for operations from land preparation to harvest by altering the crop geometry with compact varieties under HDPS. These compact genotypes also provide the scope for increasing plant population per unit area by virtue of their shorter stature, further, it provides scope for machine harvesting and also overcome the terminal moisture stress as it is one of the major detrimental factors to yield in present day changing climate and monsoon pattern mainly in rainfed area.

Nitrogen requirement may change under high density planting. Proper nutrient management is also essential for maximizing lint production while minimizing input cost in HDPS cotton. The adoption of HDPS, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yields under primarily rainfed *hirsutum* (upland) cotton growing areas.

Therefore present investigation was undertaken to find out the appropriate planting geometry and optimum nitrogen level for compact genotype LHDP1.

MATERIALS AND METHODS

The field experiment on compact cotton variety LHDP 1, during the year 2018 – 2019 was conducted in randomized block design with factorial concept with three replications at Regional Agricultural Research Station Lam, Guntur, on clay soils with slightly alkaline in reaction (pH8.2) and low in organic carbon (0.4%) and available nitrogen (179.6kg/ha), high in available phosphorus (46.4kg/ha) and high in available potassium (638.5kg/ha) content.This located at an altitude of 31.5m above mean sea level and at the intersection of16.29'N latitude and of 80.43'E longitude. The compact genotype LHDP1 sown on first week of A~~a~~ugust 2019 as per crop geometries S_1 - 60 × 10cm, S_2- 75 × 10cm, S_3- 90 × 45cm and nitrogen was applied in three equal splits at 30DAS,60DAS and 90 DAS as per treatments as four nitrogen levels N_1- 45kg N/ha, N_2- 90kg N/ha, N_3- 135kg N/ha, N_4- 180kg N/ha and whole dose of phosphorus(45kg/ ha) was applied at the time of sowing and potassium(45kg/ha) in three equal splits at 30, 60 and 90 DAS. Prevailing market price of dif~~e~~ferent inputs and seed cotton yield (kg/ha) was considered for calculation of gross and net monetary returns and return/rupee investment.

RESULTS AND DISCUSSION

Effect of crop geometry on seed cotton yield and economics: Seed cotton yield is influenced significantly due to crop geometries (Table1). Closer crop geometry 60 x 10cm recorded significantly highest seed cotton yield (4,567kg/ha) as compare to all other crop geometries tested. Superior yields at closer plant spacing might be due to more bolls/unit area. Venugopalan*et al.,* (2014), Paslawar*et al*., (2015) and Ganvir *et al.,* (2019) also reported that closer crop geometry recorded higher seed cotton yields over wider crop geometries.

Economics indicated that crop geometry significantly influenced the cost of cultivation, gross return, net returns and return/rupee investment. Maximum cost of cultivation was recorded with 60 x 10cm (Rs.73,157/ha). However, the maximum gross returns (Rs.2,42,060/ha), net returns (Rs.1,68,904/ha) and return/rupee investment(2.31) were obtained at closer crop geometry of 60 × 10cm as compared to other wider crop geometries tested.

Effect of nitrogen levels on seed cotton yield and economics: Progressive and remarkable increase in seed cotton yield with each increment in nitrogen level was noticed. However, highest seed cotton yield (3990kg/ha) was recorded with application of 135kg N/haand it was *on a par* with 180kg N/ha(3984 kg/ha) and was significantly superior over other nitrogen levels tested. Increase in yield with nitrogen application might be due to its favourable effect on plant growth and

Table 1. Influence of crop geometry and nitrogen levels on bolls/m², boll weight (g) and seed cotton yield (kg/ha)

Treatments	Bolls/m² at harvest	Boll weight (g)	Seed cotton yield (kg/ha)	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	Return/ rupee investment
Crop geometry (cm)							
S_1- 90 X 45	97.7	3.8	2,577	50,512	1,36,599	86,087	1.69
S_2 - 75 X 10	173.0	3.4	4,039	66,543	2,14,044	1,47,502	2.19
S_3 - 60 X 10	186.0	2.9	4,567	73,157	2,42,060	1,68,904	2.31
SEm±	3.3	0.04	77.6	776	4,112	3,336	0.03
CD (p=0.05)	9.6	0.1	229	2,290	12,137	9,847	0.08
Nitrogen levels (kg/ha)							
N_1-45	124.8	3.2	3,256	57,605	1,72,593	1,14,988	1.9
N_2-90	144.1	3.3	3,680	62,562	1,95,025	1,32,463	2.1
N_3 -135	163.7	3.4	3,990	66,390	2,11,475	1,45,085	2.2
N_4 -180	176.4	3.5	3,984	67,058	2,11,178	1,44,120	2.1
SEm±	3.8	0.1	89	896	4,748	3,852	0.03
CD (p=0.05)	11.1	0.1	264	2,644	14,015	11,371	0.10
Interaction (SXN)							
SEm±	6.5	0.1	155.2	1,552	8,223	6,672	0.06
CD (p=0.05)	19.2	NS	NS	NS	NS	NS	NS
CV (%)	7.4	4.5	7.2	4.0	7.0	9.0	4.0

development, which resulted in increased dry matter accumulation and associated improvement in yield attributing characters. Munir *et al.*, (2015), Meena *et al.*, (2017), Devi *et al.,* (2018) and Hiwale *et al.*, (2018) also reported that nitrogen requirement under closer crop geometry increases upto 25 per cent over and above of the recommended nitrogen dose.

Application of 180kg N/ha recorded in maximum cost of cultivation (Rs.67058/ha). However, the maximum gross returns (Rs.2,11,475/ha) and net returns(Rs.1,45,085/ha) recorded with nitrogen level of 135kg N/ha and was *on a par* with 180 kg N/ha than other levels of nitrogen tested. However, application of 135kg N/ha (2.2) recorded maximum return/rupee investment and was *on a par* with 180 kg N/haand 90kg N/ha and significantly superior over the 45 kg N/ha (1.9).Maximum gross returns and net return with increased levels of nitrogen might be due to higher seed cotton yield obtained/unit area. Increase of gross returns and net returns with increased nitrogen levels under crop geometry also reported by Khargkharate *et al.*, (2017[a]), Devi *et al.,* (2018) and Sowmiya and Sakthivel (2018).

CONCLUSION

Present study indicates that significantly maximum seed cotton yield, gross returns, net returns and return/rupee investment recorded with closer crop geometry 60 x10cm and at with application of 135kg nitrogen/ha. It might be due to maximum number of bolls for perunit area recorded under closer crop geometry and increased plant population improved the resource use efficiency.

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AMMI stability analysis for seed cotton yield in cotton (*Gossypium hirsutum* L.)

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ABSTRACT : Genotype x environment (GxE) interactions are of major concern to plant breeders. The recent stability model, AMMI is effectively applied to identify the stable genotypes over environments. The present research programme was carried out with 45 *intra hirsutum* hybrids to decipher the GxE interactions over three environments *viz.,* Regional Agricultural Research Station, Lam, Guntur; Agricultural Research Station, Jangamaheswarapuram and Agricultural Research Station, Darsi of Andhra Pradesh, for seed cotton yield/ plant along with the important seed cotton yield contributing traits. The ANOVA showed significance for all the traits *i.e.*, sympodia/ plant, bolls/ plant, boll weight and seed cotton yield/ plant, environments and (GxE) components indicating the usefulness of AMMI analysis in identifying the stable genotypes. The analysis partitioned the total G x E component into IPCA1 and residual. The hybrids, BBGH 3 x BBGH 26, BBGH 33 x BBGH 1, BBGH 3 x BGH 94, BBGH 1 x BGH 94, BBGH 3 x GHL 8 and BBGH 77 x BBGH 26, showed stable performance over environments as they had high mean values than grand mean (138.80 g) and zero IPCA score. At Lam location, the hybrids performed better with higher mean values over grand mean and high degree of interaction effects indicating their suitability to specific environments. The hybrids at Jangamaheswarapuram and Darsi locations recorded lower mean values with low GxE effects indicating their adaptability. Thus, identified stable genotypes can be used for commercial cultivation after thorough testing over locations.

Key words : Cotton, AMMI model, seed cotton yield/plant

Cotton (*Gossypium* spp.), the primary source of natural fiber of world,is the lifeline of the textile industry of least developed, developing and developed nations. It is mainly grown in 75 countries of tropical and subtropical regions of five continents indicating its suitability to diverse agro-climatic conditions. The world production of cotton is 25 million tonnes. India ranks 2nd after China in production but the yield levels are highly varied compared to the world averages. The average yield per hectare at world level is 1000 kg while in India the values are at round 450 kg/ha indicating the need to generate a road map for the development of new varieties/ hybrids to fill this gap. Among the cotton species, *G. hirsutum* is highly cultivated for its quality and yield. Heterosis is exploited for the first time in cotton in India to produce hybrids and intra hirsutum hybrids are more common in the cotton growing areas of the country. The hybrids development using diverse parents, evaluation of these crosses and stable genotypes identification form the important objectives in cotton breeding.

Targeted breeding efforts in cotton have come up with hundreds of varieties/ hybrids but the sustainable cotton breeding requires stable genotypes. Thus, stable genotypes identification is crucial in cotton breeding to overcome the GxE interactions and to get the desired as this reduces the association between phenotype and genotype and suppresses the expression of real capaciaty of a genotype. The application of stability analysis is very well known for knowing the significant GxE interactions *i.e.*, stability parameters to determine the superiority across the environments. A highly stable individual shows its consistent performance across environments with least GxE interactions. The stability model, Eberhart and Russell (1966) is very well used in all crops including cotton for the identification of stable genotypes over locations (Sirisha *et al.*, 2017) but the interaction component partition is not complete. Keeping these points in view, the present work was panned to use the recent and widely accepted model for the effective partitioning of the GxE interactions, AMMI analysis, for predicting the stable genotypes in cotton using the seed cotton yield traits.

MATERIALS AND METHODS

The experiment was conducted at three locations *viz.*, Regional Agriculture Research Station, Lam; Agriculture Research Station, Jangamaheswarapuram and Agriculture Research Station, Darsi of Andhra Pradesh, with 45 *intra hirsutum* cotton hybrids. The genotypes were sown in Randomized block fashion with three replications and each plot had two rows each of 6 m length. The spacing adapted was 120 x 60 cm. The data were collected on the seed cotton yield attributes like sympodia per plant, number of bolls per plant, boll weight (g) and seed cotton yield per plant (g). The data was analysed using the formula suggested by AMMI model to identify stable genotypes (Gauch, 1992).

$$Y_{ij} = \mu + g_i + e_j + \sum_{k=1}^{m} \lambda_k \mu_{ik} V_{jk} + \varepsilon_{ij}$$

In AMMI analysis, the GxE interaction is divided into interaction principal components (IPCA) and residual effects. This IPCA scores help in knowing the interaction and improve the accuracy of identification of stable yield components of the genotypes. Thus, the significant GE interactions help in identification of superior genotypes with stability parameters for attaining better performance of seed cotton yield cover environments.

RESULTS AND DISCUSSION

Stability analysis is helpful in understanding the stability of an individual to a varied environments and this helps in maintaining yield over locations and years. The AMMI model, a hybrid model, exploits both additive and multiplicative components and separates the additive variance before taking PCA to extract a new set of co-ordinate axes from the interaction portion for explaining the pattern using GxE main effects of the model. It also

Table 1. Analysis of variance of seed cotton yield and yield components using AMMI stability model in cotton (*Gossypium hirsutum* L.)

Source of Variation	d.f.	Sympmodia/ plant		Bolls/plant		Boll weight		Seed cotton yield/plant	
		Mean squares	Per cent explained	Mean squares	Per cent explained	Mean squares	Per cent explained	Mean squares	Per cent explained
Trials	134	4.47**		31.45**		0.26**		1339.23**	
Genotypes	44	5.75**	42.18	23.07**	24.09	0.31**	39.58	970.24**	23.790
Environments	2	36.42**	45.52	1403.24**	66.59	8.53**	49.42	63766.37**	71.070
G x E Interaction	88	0.84**	12.30	4.47**	9.32	0.04**	11.00	104.93**	5.150
PCA I	45	1.26**	77.17	4.71**	53.98	0.07**	80.21	152.38**	74.26
Residual	43	0.39	22.83	4.21**	46.02	0.02**	19.79	104.93	25.74
Pooled residual	43	0.39		4.47		0.04		57.54	
Error	270	0.75		1.13		0.01		482.66	
Total	**404**	**1.98**		**11.19**		**0.09**			

*, **represents significant at 5 % and 1 % levels, respectively.

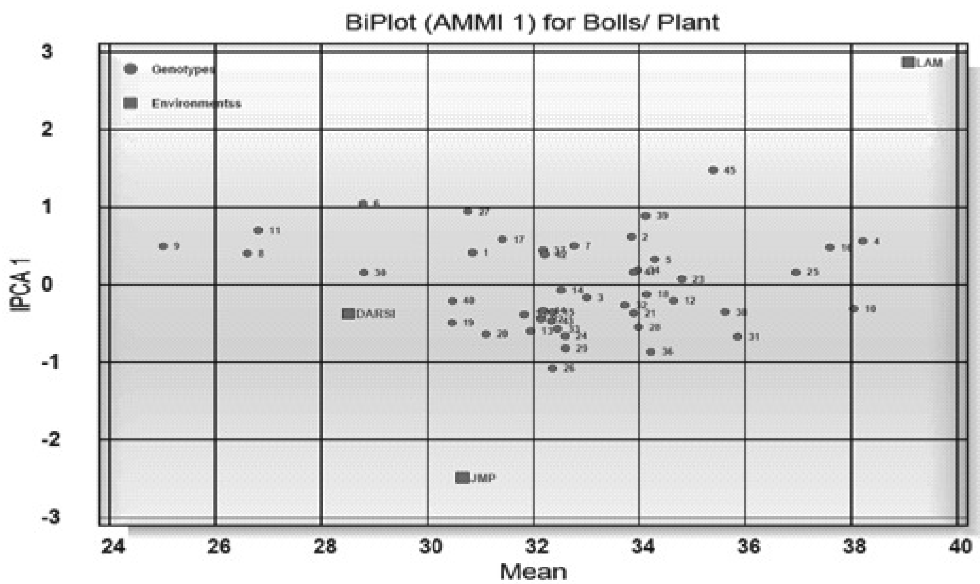

Fig 1. AMMI biplot of IPCA1 against bolls/ plant at three locations in cotton (*Gossypium hirsutum* L.).

generates a biplot for deciphering the main effects and GxE components of genotypes and environments. The genotypes with mean greater than the grand mean and PCA scores of nearly zero are the stable genotypes while, higher mean value genotypes with more IPCA values (more than zero) are considered as specific environment adaptable genotypes (Sharma *et al.,* 1998). In the present study, the GxE interaction of 45 hybrids over locations was predicted by first interaction principal component (IPCA1) and residual component (Table 1). The IPCA1 to residual values were more than one for all the traits *viz.*, sympodia/

Table -2. Mean performance of intra hirsutum hybrids for seed cotton yield and its components in cotton.

S.No.	Character	Sympodia/plant	Bolls/plant	Boll weight (g)	Seed cotton yield/plant (g)
1	BBGH-77*BBGH-3	14.52	30.86	4.37	128.42
2	BBGH-77*BBGH-26	16.19	33.85	4.29	138.56
3	BBGH-77*BBGH-33	16.12	33.01	4.36	135.99
4	BBGH-77*BBGH-1	19.00	38.22	4.58	166.15
5	BBGH-77*GHL-5	16.70	34.29	4.19	136.59
6	BBGH-77*BL-7	14.22	28.79	3.97	106.19
7	BBGH-77*GHL-8	17.44	32.77	4.56	143.04
8	BBGH-77*BGH-94	13.97	26.60	4.38	110.78
9	BBGH-77*BGH-23	13.86	25.01	3.66	87.33
10	BBGH-3*BBGH-26	18.45	38.05	4.90	176.30
11	BBGH-3*BBGH-33	15.01	26.81	4.25	107.49
12	BBGH-3*BBGH-1	17.38	34.64	4.77	157.49
13	BBGH-3*GHL-5	17.56	31.95	4.60	139.75
14	BBGH-3*BL-7	15.98	32.52	4.38	137.27
15	BBGH-3*GHL-8	16.95	32.36	4.61	141.01
16	BBGH-3*BGH-94	18.11	37.60	4.64	165.97
17	BBGH-3*BGH-23	15.34	31.41	3.91	115.82
18	BBGH-26*BBGH-33	17.83	34.14	4.28	139.74
19	BBGH-26*BBGH-1	17.24	30.46	4.64	134.71
20	BBGH-26*GHL-5	17.04	31.11	4.51	133.71
21	BBGH-26*BL-7	17.53	33.89	4.55	146.74
22	BBGH-26*GHL-8	16.73	32.15	4.80	147.25
23	BBGH-26*BGH-94	18.88	34.80	4.66	155.26
24	BBGH-26*BGH-23	18.34	32.60	4.54	142.22
25	BBGH-33*BBGH-1	19.01	36.96	4.92	172.97
26	BBGH-33*GHL-5	16.36	32.36	4.58	141.75
27	BBGH-33*BL-7	14.14	30.76	3.67	104.88
28	BBGH-33*GHL-8	16.94	33.98	4.43	142.78
29	BBGH-33*BGH-94	17.42	32.61	4.72	145.52
30	BBGH-33*BGH-23	14.52	28.80	4.07	111.75
31	BBGH-1*GHL-5	16.30	35.86	4.31	146.03
32	BBGH-1*BL-7	16.97	33.73	4.58	147.68
33	BBGH-1*GHL-8	17.23	32.46	4.65	144.38
34	BBGH-1*BGH-94	18.41	33.97	4.74	153.52
35	BBGH-1*BGH-23	16.90	31.83	4.78	145.64
36	GHL-5*BL-7	17.82	34.22	4.47	145.78
37	GHL-5*GHL-8	16.71	32.19	4.73	145.64
38	GHL-5*BGH-94	16.70	35.62	4.30	147.05
39	GHL-5*BGH-23	14.51	34.12	3.60	115.79
40	BL-7*GHL-8	17.18	30.47	4.66	135.93
41	BL-7*BGH-94	17.19	33.89	4.43	143.34
42	BL-7*BGH-23	15.67	32.22	4.67	144.20
43	GHL-8*BGH-94	15.83	32.34	4.66	143.61
44	GHL-8*BGH-23	15.92	32.19	4.64	142.75
45	BGH-94*BGH-23	17.32	35.40	3.96	132.45
	Grand mean	16.23	32.15	4.31	132.22

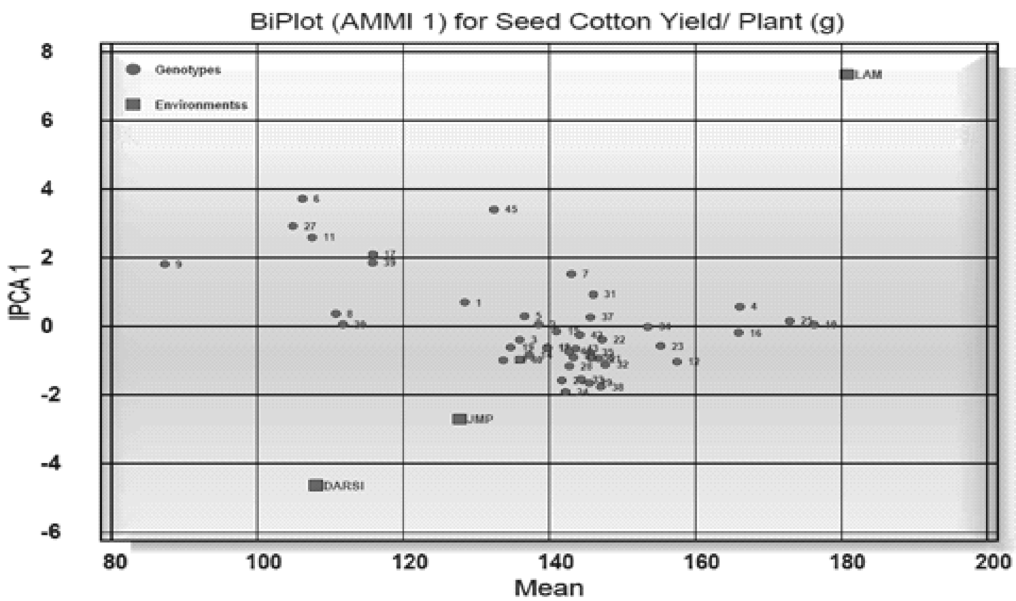

Fig 2. AMMI biplot of IPCA1 against seed cotton yield/ plant at three locations in cotton.

plant (77.17 % and 22.83 %), bolls/ plant (53.98% and 46.02 %), boll weight (80.21 % & 19.79 %) and seed cotton yield/ plant (74.26 % and 25.74 %) depicting the effective partition of interaction component with AMMI model. Significant IPCA1 and non-significant IPCA2 were recorded for all the characters.

The biplot analyses revealed the similarity of hybrids present at Lam and Jangamaheswarapuram locations in their expression and were present on the same axis and the hybrids at Darsi location recorded high GxE effects with low mean values for sympodia/ plant and boll weight (Table 2). The trait, bolls/ plant, recorded higher mean values with high levels of GxE effects for the hybrids at Lam location whereas the hybrids at Darsi location had low GxE effects with low mean values (Fig 1). The hybrids performed better with higher mean values but with high interaction effects at Lam location indicating their preferential expression in this environment for seed cotton yield/ plant (Fig 2). The environments, Jangamaheswarapuram and Darsi, had high levels of GxE with lower mean values for the trait, seed yield/ plant.

The biplot analysis also identified the stable hybrids which had higher mean values than the grand mean and zero IPCA score. The hybrid, BBGH 1 x BL 7, recorded high mean over grand mean and zero IPCA for sympodia/ plant.The hybrids, BBGH 26 x BGH 94 and BBGH 3 x BL 7, were found to be stable with zero IPCA and mean value greater than grand mean for bolls/ plant. For boll weight, the hybrids, BBGH 1 x BGH 23, BBGH 77 x BBGH 1, GHL 5 x BL 7 and BBGH 1 x GHL 8, were denoted as stable as they recorded higher mean over grand mean and zero IPCA score. The hybrids, BBGH 3 x BBGH 26, BBGH 33 x BBGH 1, BBGH 3 x BGH 94, BBGH 1 x BGH 94, BBGH 3 x GHL 8 and BBGH 77 x BBGH 26, were noted as the stable as these hybrids performed very well over locations with high mean values than grand mean and least IPCA score for seed cotton yield/ plant. These results are in similar to the earlier studies reported in cotton by Reddy and Sarma (2014) and Pretorius *et al.*, (2015).

The stable hybrids for seed cotton yield were not stable for the expression of yield contributing traits like number of sympodia, number of bolls and boll weight indicating the necessity of further studies to confirm these results and their exploitation in the cotton breeding.

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Suitability of different tillage systems over conventional tillage for cotton production

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Presently, cotton is considered an exclusively mechanized crop in terms of tillage operation. Conventional tillage for cotton production involves use of disk harrow, cultivator followed by planking to smooth out the seedbed and intercultural operations for weed control. Cost of cultivation has increased with the intensive use of heavy machinery to perform different field operations especially tillage. Costs associated with conventional tillage operations include fuel, labor, equipment, and maintenance are higher than conservation and no-till systems (Buman *et al.,* 2005). Intensive use of heavy machinery for different field operations is not only increase cost of cultivation, but also deteriorate soil physical conditions by soil compaction, resulting in decline in productivity. Although, different tillage systems have different agronomic benefits, but continuous tillage to the same depth increase the problem of soil compaction (Amanullah *et al.,* 2010). Cotton seedlings are easily affected by soil conditions. Reduction in root biomass, depth of root penetration and delayed seedling emergence as result of increase in soil compaction was reported by Getmos and Lellis (1997). Soil compaction reduces the oxygen supply and prevents seeds from germinating. So, there is need to identify tillage system for cotton production which favour root penetration and productivity.

There is a potential to cut production costs, and improve the sustainability of cotton production systems by reducing number of operations in conventional tillage under north zone of India. There is a larger uncertainty among the tillage system for cotton production. Therefore, present study was attempted to investigate different tillage systems for their conservational benefits, persistence and their impact on cotton growth and yield over conventional tillage systems.

MATERIALS AND METHODS

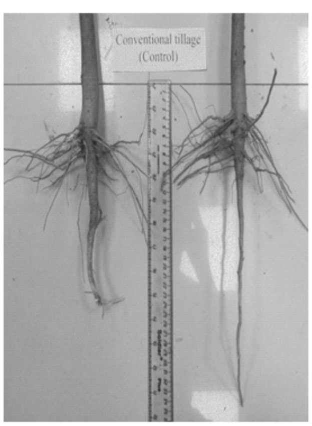
Field experiment was conducted during 2017 and 2018 in *kharif* season at Punjab Agricultural University, Regional Research Station, Bathinda in the Trans-Gangetic Agro Climatic Zone of India. Soil of the experimental field was classified as alluvial, loamy sand with pH 8.1, EC 0.21 dS/m, organic carbon 0.34 per cent, available N 157 kg/ha, available P_2O_5 14.6 kg/ha and K_2O 284.7 kg/ha. Experiment consisted five treatments *i.e.* T_1: Strip tillage (strip tillage and sowing in single operation), T_2: Zero tillage (manual sowing with khurpa), T_3: Mould board *f.b.* conventional tillage, T_4: Sub-soiling *f.b.* conventional tillage and T_5: Conventional tillage (control) laid out in a completely randomized complete block design.

RESULTS AND DISCUSSION

The results indicate that different tillage systems had significant effect on cotton growth and productivity. Germination significantly higher under conventional tillage, mould board *f.b.* conventional tillage and sub-soiling *f.b.* conventional tillage as compared to zero tillage during both the years of study. During 2017, germination under strip tillage was reduced significantly as compared to conventional tillage. Plant height and bolls/plant were significantly higher under strip tillage and mould board *f.b.* conventional tillage as compared to zero tillage and conventional tillage during both the years. While, sub-soiling *f.b.* conventional tillage was statistically at par with strip tillage and mould board *f.b.* conventional tillage with respect to plant height and bolls/plant during both the years of study. Seed cotton yield was significantly higher under strip tillage as compared to zero tillage and conventional tillage; however it was statistically *at par* with mould board *f.b.* conventional tillage and sub soiling *f.b.* conventional tillage. Strip tillage produced significantly higher seed cotton yield by margin of 10.9 and 17.2 per cent as compared to conventional tillage during 2017 and 2018, respectively. However, seed cotton yield under mould board *f.b.* conventional tillage was higher by 5.9 and 6.5 per cent as compared to conventional tillage during 2017 and 2018, respectively. Sub soiling *f.b.* conventional tillage had 5.0 and 7.3 per cent seed cotton yield over the conventional tillage during 2017 and 2018, respectively. While, seed cotton yield was reduced by 10.4 and 8.1 per cent under zero tillage as compared to conventional tillage.

Further perusal of data for root penetration study 2018 showed that tap root length was significantly maximum under strip tillage as compared to other tillage systems and

Conventional tillage (control)



Strip tillage

Mould board f.b. conventional tillage

Zero tillage

Table 1. Effect of different tillage systems on germination, growth, yield and monetary parameters of cotton

Treatments	Germination (%)		Plant height (cm)		Bolls/ plant		Seed cotton yield (kg/ha)		B:C ratio		Tap root length (cm) during 2018 (DAS)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	35	85
T_1: Strip tillage (tillage and sowing) in single operation	92.4	94.0	170.7	178.8	51.6	60.8	2569	2879	1.72	1.93	15.2	49.4
T_2: Zero tillage (Manual hoeing with *khurpa*)	90.3	88.3	147.5	161.1	39.7	46.8	2076	2256	1.31	1.45	9.4	28.2
T_3: Mould board *f.b.* conventional tillage	97.5	94.8	165.9	175.3	49.3	58.0	2454	2615	1.42	1.53	13.7	37.3
T_4: Sub-soiling *f.b.* conventional tillage	96.2	92.7	165.0	169.6	47.8	53.9	2433	2635	1.41	1.55	12.2	35.6
T_5: Conventional tillage (control)	96.8	95.8	157.7	164.3	41.7	50.7	2317	2456	1.45	1.56	9.9	30.7
CD (p=0.05)	4.2	3.8	9.5	10.7	4.8	6.4	212	269	0.14	0.17	1.2	4.4
CV (%)	2.90	2.64	3.81	4.11	6.72	7.65	5.52	6.81	5.71	6.91	6.50	7.96

significantly shallower tap root was observed under zero tillage and conventional tillage. In monetary analysis, strip tillage had significantly higher benefit cost ratio as compared to other tillage systems.

CONCLUSION

The study concludes that, strip tillage is the best tillage system for cotton production in terms of better growth and productivity as well as higher monetary returns. It is best from resource conservation point of view for cotton production.

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SESSION PROCEEDINGS AND RECOMMENDATIONS

National Symposium

on

“Cotton Production Technologies in the Next Decade : Problems and Perspectives”

at

Odisha University of Agriculture and Technology,

Bhubaneswar, Odisha-751 003

January 22-24, 2020

Jointly Organized by :

Cotton Research and Development Association (CRDA)

CCS Haryana Agricultural University, Hisar-125 004

and

Odisha University of Agriculture and Technology

Bhubaneswar-Odisha-751 003

In collaboration with

Indian Council of Agricultural Research (ICAR)

New Delhi-110 001

Programme

Wednessday, January 22, 2020

9.00-10.30	Registration

Inaugural Programme

Agenda

Venue :	**Dr. M.S. Swaminathan Hall, OUAT, Bhubaneswar**
Date :	**22-01-2020**
Time :	**10.30 a.m.**
10.30 am :	Arrival of Chief guest and other dignitaries and presentation of flower bouquet
10.30 am :	Inauguration of the Symposium by Lightining of Lamp
10.35 am :	Inaugural Song
10.40 am :	Welcome address by Dr. K. K. Rout, Dean, College of Agricultyure, OUAT
10:45 am :	Address by Dr. S.S. Siwach, President, CRDA, CCS HAU, Hisar
10.50 am :	Address by the Chief guest, Dr. N.S. Rathore, Hon'ble Vice-Chancellor, MPAUT, Udaipur
11.05 am :	Release of Publications a) Compedium of Lead and Invited Papers b) Book of Oral Presentations c) Book of Abstracts and Souvenier d) Soft copy of all publications
11.10 am :	Felicitation of Achievers (Award Ceremony) a) Life Time Achievement Award b) Professional Excellance Award c) Corporate Advisors Honour d) Sponsorship Honour
11.25 :	Presidents' Remarks by Dr. P.K. Agrawal, Hon'ble Vice-Chancellor, OUAT,
11.35 :	Felicitations of the Dignitaries on the dias
11.40 :	Vote of Thanks by Dr. M.S. Chauhan, Secretary CRDA, CCS HAU, Hisar
11.50 :	National Anthem
11.55 :	Hi-Tea

Inaugural Session

Chief Guest : **Dr. N.S. Rathore**

Hon'able Vice Chancellor, MPUAT, Udaipur

President : **Dr. P.K. Agrawal**

Hon'able Vice Chancellor, OUAT, Bhubaneswar

Rapporteurs : **Dr. M.S. Chauhan**

Secretary CRDA, CCS HAU, Hisar

Dr. R.K. Patnaik

Organizing Secretary, OUAT, Bhubaneswar

The Inaugural Session of the National Symposium on "Cotton Production Technologies in the Next Decade : Problems and Prospects" jointly organized by Cotton Research and Development Association (CRDA) CCS Haryana Agricultural University, Hisar and Odisha University of Agriculture and Technology, Bhubaneswar in collaboration with Indian Council of Agricultural Research (ICAR), New Delhi Dr. K.K. Rout, Dean College of Agriculture, OUAT, Bhubaneswar welcome the dignitaries on the dias, delegates, press and media, students and guests. Dr. N.S. Rathore, Hon'ble Vice-Chancellor, MPUAT, Udaipur was the Chief Guest of the function and Dr. P.K. Agrawal, Hon'ble Vice-Chancellor, OUAT, Bhubhaneswar presided over the function. Others on the dias were Dr. K.K. Rout, Chairman Local organizing Committee cum Dean College of Agriculture, Bhubaneswar, Dr. S.S. Siwach, President, CRDA, CCS HAU, Hisar, Dr. M. S. Chauhan, Secretary, CRDA, CCS HAU, Hisar and Dr. R.K. Patnaik, Organizing Secretary and Associate Dean College of Agriculture, Chiplima graced the occassion. The inaugural function started with lightining of lamp by the dignitaries on the dias followed by inaugural song.

Dr. K.K. Rout, Chairman local organizing committee cum Dean College of Agriculture, OUAT Bhubaneswar welcome the dignitaries on the dias, guests and participants. Dr. R.K. Patniak, organizing secretary of the National Symposium throw light on the organizational part of the symposium. He also appreciated the gesture of participants who have come from far far distances to make the symposium a grand success. He also pointed out the problem of non cultivation of *Bt* cotton in Odisha state. He said that no doubt the Govt. of Odisha making all efforts to make the people of Odisha State a self sufficient state. Dr. S.S. Siwach, President of CRDA informed the house about he establishment and achievements of CRDA. He also pointed out the whitefly problem in north India and pink bollworm in central and south and stress the importance of inter-displinary approach to tackle the challenging problems.

11.05 am :	**Release of publications :**		
	a) Compedium of Lead and Invited Papers	:	**Dr. N.S. Rathor,** Hon'ble Vice-Chancellor, MPUAT, Udaipur
	b) Book of Oral Presentations	:	**Dr. P.K. Agrawal,** Hon'ble Vice-Chancellor, OUAT, Bhubaneswar
	c) Book of Abstracts and Souvenier	:	**Dr. K. K. Rout** Chairmain, Local Organisizing Committee cum Dean, College of Agriculture, OUAT, Bhubanswar
	d) Soft copy of all Publications	:	**Dr. S.S. Siwach,** President, CRDA, CCS HAU, Hisar

11.10 am : **Felicitations of Achievers (Award Ceremony)**

Life Time Achievement Award

a) **Dr. Ashok Kumar Dhawan**
Former Associate Director Extension Education
PAU, Ludhiana

b) **Late Dr. P.D. Sharma**
Former Senior Entomologist, Cotton,
CCS HAU, Hisar

Professional Excellance Award

a) **Dr. (Mrs.) A Sarada Devi**
Former Dean,
College of Home Science, ANGRAU, Hyderabad

b) **Dr. Sasangagouda S. Janagoudar**
Former Vice Chancellor,
UAS, Raichur and Dharwad

c) **Dr. Edara Narayana**
Director Planning and Monitoring
ANGRAU, Hyderabad

d) **Dr. Iswarappa S. Katageri**
Dean, College of Forestry

UAS, Sirsi

e) **Dr. Ravi Kumar Patniak**
Associate Dean, College of Agriculture,
OUAT Chiplima

f) **Dr. D.B. Deosarkar**
Associate Dean and Principal College of Agriculture
VNMKV, Golegaon

g) **Dr. Satyanarayana Rao**
Associate Director of Research
UAS, Raichur

h) **Dr. Devendra Pal Saint**
Associate Director (S and F)
MPUAT, Udaipur

i) **Dr. Ramesh Thatikunta**
Associate Dean, College of Agriculture
PJTSAU, Warangal

j) **Dr. A.H. Prakash**
Project Co-ordinator and Head
CICR-Regional Station, Coimbatore

k) **Dr. Shreekant S. Patil**
Former Director of Research
UAS, Dharwad

Coorporate Advisors Honour

a) **Dr. R.D. Shroff, CMD**
UPL, Mumbai

b) **M. Prabhakar Rao, CMD**
Nuziveedu Seeds, Secudrabad

c) **Dr. M. Ramasami, CMD**
Rasi Seeds, Attur

d) **Dr. H.V.S. Chauhan, President**
Indofil Industries, Mumbai

Honouring Sponsors

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f) Department of Biotechnology, GOI, New Delhi
g) Science and Engineering Research Board (SERB), GOI, New Delhi
h) National Bank for Agriculture and Rural Development (NABARD), Mumbai
i) Cotton Corporation of India, Mumbai
j) Dhanuka Agritech Ltd., Gurugram
k) Seed Works India, Hyderabad

Honouring the dignitaries on the dias

a) Dr. N. S. Rathore, Honourable Vice Chancellor, MPUAT, Udaipur, **Chief Guest**
b) Dr. P. K. Agrawal, Honourable Vice Chancellor, OUAT, Bhubaneswar, **President**
c) Dr. K. K. Rout, Dean College of Agriculture, OUAT, Bhubaneswar, **Guest of Honour**
d) Dr. S. S. Siwach, President CRDA, CCS HAU, Hisar **Guest of Honour**
e) Dr. M. S. Chauhan, Secretary, CRDA, CCS HAU, Hisar **Guest of Honour**
f) Dr. R. K. Patnaik, Associate Dean, COA, Chiplima, Organizing Secretary, **Guest of Honour**

Dr. P.K. Agrawal, Vice-Chancellor of OUAT, Bhabaneswar emphasized the role of state Government and the union Govt. to uplift the status of formed community particularly the weaker section of Odisha. He also narrated different schemes for the benefit of farmers which are being operated by the state govt of Odisha. He also emphasized the role of different committee for making this programme a grand success.

The Chief Guest Dr. N.S. Rathore, Hon'ble Vice-Chancellor, MPUAT, Udaipur addressed the august gathering of delegates, guests, students and press and media. He expressed that the farmers feel that cotton is the safest crop though challenging crop. Development of state varieties and Bt technology is under progress and a continuous process by the breeders to do the job for the development of high yielding, pest resistant and suitable for textile industry. He also narrated that Union Govt. of India is working hard for anouncing different scheme for the benefit of farmers particularly who are having very small holdings. Now the Govt. have taken the corrective measures to tackle the problems of farmers and he urged the scientist to realise the problems with minimum inputs. Dr. N.S. Rathore, Hon'ble Vice-Chancellor, MPUAT, Udaipur and the Chief Guest of this Inaugural programme also emphasized the role of different departments for the uplift of farmers of the state and the country in particular by inter-displinary approach the important threats can be solved without any delay. He also thanked the participants and congratulated the winner of different awards and advised the young scientist to do hard work at early stage as it will pay you in the later part of your life.

Dr. M.S. Chauhan, Secretary CRDA proposed vote of thanks. He thanked the ICAR and OUAT for agreeing to organize the National Symposium and OUAT for agreeing to the proposal of CRDA to organize the National Symposium at OUAT, Bhubaneswar. He thanked the delegates who have come from far far distances to attend the symposium and to make the symposium a grand success. He thanked the different committee members who have workd day and night to make this programme a grand success. He thanked with core of his heart to different sponsors who have generously contriubted with financial support deserves special appreciation because without their support the programme could not be so successful. He thanked press and media, guests and others who have directly or indirectly connected with the organizational part of this symposium. The symposium ended with “National Anthem”.

Technical Session-I : (Lead Papers)

Venue	:	**M.S. Swaminathan Hall**
Date	:	**Wednesday, 22 January, 2020**
Time	:	**12.30 to 14.00**
Chairman	:	**Dr. S. S. Siwach,** President, CRDA
Co-Chairman	:	**Dr. L. M. Garnayak,** Prof. Agronomy, OUAT
Coordinator	:	**Dr Sarbani Das,** Asstt. Prof Ext. Edu. OUAT
Rapporteur	:	**Dr Asish Jain,** Asstt. Scientist, CCS HAU, Hisar
		Dr. Tusar Patel, Asstt. Prof. NAU, Surat

Six papers were listed in the programme but only four papers were presented.

a) Topic : Innovative approaches in the breeding cotton :

Speaker : Dr. Shreekant S. Patil, Former Director of Research,

UAS, Dharwad

He said that historically cotton is valued as a high remunerative crop and at the same time it is haunted by very complex and voracious pests which constantly affect the diminish remunerative value of cotton. He also said that the another bigger prosterm of cotton cultivation in Indian sub-continent is that here there are no efforts made to reduce dependence on labor for cultivation of cotton unless it is made essential labor intensive and bring mechanized cultivation, it may become difficult to cultivate cotton against the lower cost of cultivation in many countries where machine takes care of the cultural operations. Conventional breeding methods are easier in execution and cost lesser as compared to genetic gain and improvement in productivity and other traits received through these approaches. Genetic improvement of cotton is aimed at developing improved varieties and potential hybrids. There is a clear lack of research in plant body system and procedures of varietal improvement of hybrid development.

b) Topic : Polyethylene mulching- A boon or bane for cotton cultivation

Speaker : Dr. P. Nalayini, Principal Scientist (Agronomy).

CICR- Regional Station, Coimbatore.

Dr. P. Nalayini said that mulching has been practiced in India since long time using mainly the crop residues like straw, trash, stalk and leaves etc. but of late plastic mulches have come into use due to its inherent advantages of efficient moisture conservation, weed suppression and maintenance of soil temperature for factor mineralization. The advantage of using plastic mulches for the production of high value vegetable crops have been recognized since 1950s in United states and European countries and its use for moisture conservation, weed control and enhancing crop productivity has been explored for cotton based cropping system and the results were highly encouraging and it has potential to be exploited fully so that the recent concept of more crop per drop of water could be achieved. Poly mulching prevent direct evaporation of moisture from soil and thus limit the water loss and conserve moisture. The moisture that evaporates under poly mulching is condensed below the mulched layer and reused by the crop.

c) Topic : Integrated used management in cotton in India

Speaker : Dr. Samunder Singh, Prof Head, Department of Agronomy

CCS Haryana Agricultural University, Hisar

India has the largest and production of cotton in the world. After the adoption of *Bt* cotton, India's cotton acerage and yields increased by a fifth between 2005-2006 and 2016-2017, though in 2017-2018 productivity was lower by a per cent. The average cotton productivity in India is much lower due to adopted cultivars, cultivation conditions and onslaught of insect pest including weeds. Due to wide spaced crop with slow initial growth, weed are potent enough to lower yield from 10-90 per cent depending upon weed management practices with technology innovation. The present day agriculture is embracing efficient management systems to meet the even increasing population demand for food, fibre and fuel. Under that condition, it is important to lower the cost of cultivation and increase the yield under an integrated weed management system which includes crop diversification, cultivars competitiveness with early vigor, crop geometry (narrow row plantation) rows orientation to sunlight. Choosing cultivars with early vigor use of narrow row planting, orienting crop rows with regard to sunlight, planting time, irrigation and fertilizer application time and adjusting planting density are some of the agronomic approaches that could enhance the competitiveness of cotton over weeds. Application of pre plant incorporation of herbicides and pre and post use of weedicides. It is desired to rotate herbicides and crop for avoiding dominance of a particular weed species or evaluation of resistant weeds to herbicides.

d) Topic : Challenges in commercialization of natural dye technology on cotton

Speaker : Dr. A Sarada Devi, Former Dean, College of Home Science

ANGRAU, Hyderabad

Dr. Sarada Devi said that presently the interest on natural dyes in growing worldwide irrespective of the existence of these dyes in the past. The necessity to protect the environment from hazardous pollutants, depletion of natural sources, ecological imbalance, distorted environment resulting from pollutants caused by the over dozing of toxic substances in use of synthetic dyes in dyeing textiles, associated human health problems etc is unable to launch a more sustainable and safer alternatives. The global natural dye market is driven by the innovation in treatment plants and systems. The demand for natural dye cotton and other cellulostic fibre is increasing and it is expected to grow very fast in near future. Many natural dyes sources are identifies to colour textiles, but very few are found to possess good potential for obtaining fast shades. Today natural dyes have a variety of applications. They are used not only in textile dyeing and functional finish, but also as food and cosmetic colorants, cosmetics healing, additivetives handicraft, eco colour, powders for human use.

Technical Session-II : (Invited Papers)

Venue	:	**M.S. Swaminathan Hall**
Date	:	**Wednesday, 22 January, 2020**
Time	:	**15.00 to 16.30**
Chairman	:	**Dr. P.P. Shastry,** Dean COA, Khandwa
Co- Chairman	:	**Dr. D. Monga,** Head CICR Regl. Station, Sirsa
Coordinator	:	**Sarbani Das,** Asstt. Prof. Ext. Edu., OUAT
Rapporteurs	:	**Dr Kulvir Singh,** Agronomist PAU,RS, FArdkot
		Dr Pramod Nayak, Officer in Charge AICRP OUAT

Six papers were scheduled in the session but only five were presented by the respective speakers.

a) Topic : Business perspective and entrepreneurship opportunities in cotton stalk by product based on industry in India

Speaker : Dr. V.G. Arude, Scientist

Central Institute for Research on Cotton Technology, (CIRCOT) Mumbai

Dr. Arude said that cotton is grown in about 100 countries and traded in around 150 countries worldwide. Cotton is cultivated mainly for its fibre which is the most important commercial product apart from the cotton seed and cotton stalk as its valuable by products. Linter, hull and meal are the important by products obtained after extracting oil from the cotton seed which are used for preparation of value added products. In India, very limited value addition is done to cotton stalk. Most of the cotton stalk produced is treated as waste, though about 5-6 per cent being used for commercial purpose and around 15-20 per cent is used as fuel by rural masses and remaining bulk of cotton is burnt off in the field after leading to severe environmental pollution. Cotton based industries are underdeveloped in India owing for several impediments including lack of logistic for supply of cotton stalks, lack of availability of equipment for uprooting and chiping, lack of awareness, and information among the farmer about the value added technologies, inadequate government policies to support the development of cotton by product industries etc.

b) Topic : Employing molecular breeding for genetic improvement of cotton fibre quality : Progress and Perspectives

Speaker : Dr. N. Manikanda Boopathi, Prof Biotechnology,

Department of Biotechnology, CPMB and B, TNAU, Coimbatore.

Dr. Boopathi said that genetic improvement of fibre quality traits in cotton with enhanced input responsive and adoption to resource limited environments through molecular breeding has long been practiced at TNAU, Coimbatore. The low rate of polymorphism among *Gossypium* species, in comparison with the other species has been a major constraint in the development of high density genome help. To overcome these constraints, a second approach of genetic mapping proposed based on many mapping populations for a census genetic mapping in which most of the mapped markers will be common land marks in all the population that were analyzed . Consensus genetic mapping has several advantages over individual genetic map for which many crop species have already worked out for the consensus map with the same constraints of polymorphism as that of cotton. Such efforts have enormous potential in elucidating the molecular mechanism for the investigating traits and more importantly in rapid and precise genetic improvement of cotton through molecular breeding.

c) **Topic : Speed Breeding in cotton for increasing production in the next decade :**
Speaker : Dr. (Mrs.) Vinita Gotmare, Principal Scientist, Breeding,
Central Institute of Cotton Research (CICR), Nagpur

Since Dr. Gotmare could attend the symposium due to some unavailable reasons therefore her paper was presented by Dr. S. Manekam, Principal Scientist, CICR Regional Station, Coimbatore. Dr. Manikam said that speed breeding is a crop breeding technique originally developed by NASA in the eighties to help grow crops in a space and can hasten the process of developing new crop varieties, over the next 30 years, the global human population is expected to grow by 25 per cent and research 10 billion. Conventional breeding approaches have so far produced nutrition crops with high yields that can be harvested mechanically to meet the food needs of the growing population. But the current pace of yield increase for major crops, including wheat, rice, maize is insufficient to meet future demands. Breeders and plant scientists are under pressure to improve existing crops and develop new crops that are higher yielding, more nutritious, pests and disease resistant and climate smart. A key limiting factor for plant breeding, the long generation time of crops, which typically allow one or two generations for year, has been alleviated by "Speed Breeding" protocols that are extended photoperiods and controlled temperatures to reduce the generation time by more than half. Genetic resources such as land races are promising for future production demands because many are already adopted to vary specific target environments and process excessively advantageous characteristics such as biotic and abiotic stresses resistance.

d) **Topic : Performance of GEAC approved *Bt* cotton hybrids in Haryana,**
Speaker : Dr. R. S. Sangwan, Head, Cotton Section,
CCS Haryana Agricutlural University, Hisar

Dr. Sangwan said that a total of 100 promising *Bt* hybrids approved by GEAC for cultivation in north zone evaluated alongwith *Bt* check hybrid seed cotton guide, plant height, boll weight, monopods/plants, boll/plant, gimming outturn, seed index and fibre quality traits namely upper half mean fibre length, uniformity ratio, tenacity and micronaire value. Seed cotton yield ranged from 2346 to 5340 kg/ha. Higher yielding hybrids were tolerant/ resistant for pests were identified and recommend to the farmers. Many of the *Bt* cotton hybrids were very poor in seed cotton yield. Therefore, screening and evaluation of approved *Bt* cotton hybrids is essential for their identification and recommendations to the farmers for increasing the productivity and production in then country. Sufficient genetic variability exists for different traits. Characteristics of cotton plant type were described based on the performance of best genotypes *Bt* cotton has made a substantial contribution in reduction in application of insecticidal sprays for the control of key pest such as bollworms.

e) Topic : Agronomic management for rainfed cotton

Speaker : Dr. D.D. Patel, Principal Scientist, Agronomy,

NAU, Cotton Research Station, Bharuch

Dr. Patel explained that it is widely recognized that the average yield of rainfed cotton, even in developed countries, seldom exceed half of the theoretical potential yield, if all the rain water used efficiently. It is proposed at this "gap" between actual and potential yield can be effectively address using existing technology that do not harm ecosystem, contrary many improve it. Agronomic practices that can improve crop yield and soil health will sustain, such improvements in the long term are inter-linked. Effective agronomic managements in rainfed cotton required planting coupled with selection of proper agro-technicians with its right time of field application. Though the main component are not the universal but locations specific but ensure higher yield are selection of cultivators, sowing time, soil and water conservation practices, planting geometry and plant population, weed management, inter- cropping and moderate use of manures and fertilizers. Cotton is a long duration crop having initially slow growth rate is highly amenable for inter cropping with any short or medium duration crop. Intercropping is getting higher emphasis because of yield stability and more return/ unit area even under adverse conditions. In tradition cotton belt, cotton based intercropping systems are popular for more tangible reasons as it covers risk.

Session-III Brain Storming

(Interaction between industry officers and SAU's Scientists)

Venue : **M. S. Swaminathan Hall**

Date : **Wednesday, 22 January, 2020**

Time : **17:00-18:00**

Chairman : **DR. R.D. Shroff,** CMD, United Phosphorus limited, Mumbai

Co-Chairman : **Dr. A.H. Prakash,** Project coordinator AICCIP, Coimbatore

Coordinator : **Dr. Arabinda Dhal,** OUAT

Rapporteurs : **Dr.S.K. Sain,** Scientist CICR, Sirsa

: **Dr. R.K. Mahapatra,** Prof Entomology, OUAT

The topics of discussion

1. Pink bollworm- Becoming threat to cotton cultivation
2. Mechanical picking- Status
3. *Bt* Cotton bane in Odisha – Reasons/ solutions
4. Leaf curl virus and whitefly- Problematic in *Bt* cotton

This session was purposely planned to have a healthy and fruitful discussions on the burning topics of cotton cultivation. Since only 1-2 senior position officers from the industry were present but they declined to takr any decision on the subjects, therefore keeping this in mind, the session was postponed to 24th January during the closing day but the things cannot mature and ultimately this session was cancelled even on 24th January, 2020.

Technical Session – IV (Oral Presentation for Award)

Concurrent Session : (Crop Improvement, Biotechnology and Post Harvest Technology)

Venue	:	**M.S. Swaminathan Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**9:00- 11:30am**
Chairman	:	**Dr. Pankaj Rathore,** Director PAU, Regl. Station, Faridkot
Co- Chairman	:	**Dr. Tapas Kumar Mishra,** Prof Plant Breeding and Genetics, OUAT
Session Coordinator	:	**Khitish Sarangi,** Asstt. Prof. Agril. Economic, OUAT
Rapporteurs	:	**Dr. Dharminder Pathak,** Assoc. Prof. PAU, Ludhiana
		Dr. Manasi Dash, Asstt. Prof PBG, OUAT
Evaluators	:	**Dr B. Pardhan,** Prof Head PBG, OUAT
		Dr. G. Rout, Prof Head, Biotechnology, OUAT
		Dr. R. S. Sangwan, Head Cotton, CCSHAU, Hisar

Nine papers were scheduled in this session but only ten presented their work as three added their names at the spot.

a) Topic : Identification of Cotton hybrid through PCR based molecular markers
Speaker : Dr. B.K. Rajkumar, Scientist,
NAU, Main Cotton Research Station, Surat

Dr. Rajkumar said that cotton is a natural fibre of vegetable orgin and plays a vital role in trade, economy, industry, employment and foreign exchange.

India was the first country in the world to domesticate cotton for the production of cotton fibre, cotton being often criss pollinate crop, the genetic purity of cotton hybrid seed is adversely affected by the foreign pollen. Low genetic purity would cause seed suppliers a great loss from the planters claim and could make it easy for a competitor to steal the inbred parent of a hybrid. Therefore, it is critical for seed suppliers to control seed genetic purity and quality before marketing. Hence, in order to get better returns from the hybrids, greater seed purity and quality are emphasized. Traditionally, it has been the practice to carry out grows out last (GOT) to analyze the genetic purity if hybrid seed using morphological traits. Though morphological and floral characterization of the plant to determine true hybrid. In the present study it was demonstrated that RAPD, ISSR and SSR banding pattern of the parents compared with their respective hybrids clearly recognized true hybrids in case of heteroallelic markers and even combinations of markers can also be used to identify the true hybrid.

b) Topic : G. Cot. Hyb- 12 (BG-II)- A high yielding hybrid for irrigated and rainfed ecosystem of Gujarat,

Speaker : Dr. D.H. Patel, Plant Scientist, Breeding,

NAU, Main Cotton Research Station, Surat

Dr. Patel said that cotton plays a vital role in the economy of India. Cotton and its products account for 30 per cent in foreign exchange and 3 per cent in GDP of the country. The last decade has witnessed unparallel growth of the cotton in Gujarat even recorded in the annals of agriculture. G.Cot hybrid-12 was a popular hybrid with the stay green characters before *Bt* introduction. This versatile hybrid is a medium duration, with comparatively big boll size, high yielding and tolerant to pest and diseases, or specially suit to irrigated and rainfed both situations. The femalr parent was converted to BG-II background and the hybrid was developed using converted female plant and non *Bt* male parent. The bioefficacy study against *Spodoptera* and *Helicoverpa* was carried out at MCRS, Surat. Performance of the hybrid across locations and situations clearly exhibited its significant superiority in yield over its non- *Bt* counterpart and the lint yield was also significantly higher in irrigated conditions. The hybrid and the counterparts non *Bt* produced good mature fibres. The population of thrips and predators showed non- significant values amongst hybrid, its counterparts and other *Bt* hybrids. No damage to square green bolls, open bolls and locule was observed.

c) Topic : Heterotic studies in diploid cotton (*Gossipium arboretum* L.) under rainfed conditions,

Speaker : Dr. S.S. Patel, Plant breeder,

MPKV, Oilseed Research Station, Jalgaon

Dr. Patel's investigation was to estimate heterosis with an objective of exploring possibilities of its commercial utilization under rainfed conditions. Marked economic heterosis was observed for most of the characters namely seed cotton yield, bolls/ plant, boll weight. The standard heterosis was calculated over standard hybrid check. The yield levels obtained in all the crosses and hybrid check are very low due to adverse environmental session, however the heterosis obtained are positive and highest as compared to hybrid check. There are several diploid hybrids and varieties under cultivation, this indicates that there are much more scope of development of hybrids in diploid cotton and efforts are being taken. The area under cotton crop is increasing day by day due the most remunerative cash crop. *Desi* (diploid) cotton varieties and hybrid are also maintaining its importance due to its low cost of cultivation and thrives well under rainfed conditions. Moreover, the marginal farmers are preferring diploid hybrids and varieties due to inherent biotic and abiotic stresses resistance characters. These are preferring well under rainfed conditions. It was observed that phenomenon of heterosis was a general occurrence, however, its magnitude varied with characters. There are several diploid hybrids and varieties under cultivation, this indicated that there is much more scope of development of diploid hybrids.

d) Topic : Artle interspecific hybridization between *Gossypium hirsutum* and G. armourianum : Morphological, cytological and molecular characterization of hybrid,

Speaker : Dr. L. Mahalingam, Scientist, Biotechnology,

Department of Cotton, TNAU, Coimbatore

Dr. Mahlingam explained that triploid F1 interspecific hybrid were synthesized between *Gossypium hirsulum* L and the wild species *G. armourianum*. The F1 hybridity was confirmed by morphological, cytological and molecular markers approaches. Variable expression of petal, spot, anther colour and filament colour was observed in F1 hybrid. The F1 hybrid interspecific hybrids had more than 97 per cent of sterile pollen grains. Out of 11 SSR markers which were polymorphic between parents, 5 markers unambiguously confirmed the hybrid status of interspecific hybrid. These hybrids may serve as useful genetic source for the infusion of jassid resistant gene to *Gossypium hirsutum* cultivated genotypes. These materials can be used as bridges for the transfer of pest and diseases resistant genes from the wild species to cultivated varieties.

e) Speaker : Breeding for ultra low Gossypol cotton seed (ULGCS),

Topic : Dr. A. Manivannan, Sr. Scientist, Plant breeding,

CICR, Regional Station, Coimbatore

Dr. Manivannam said that cotton is used as dual purposes crop for fibre as well as for oil. There is a considerable amount of variation for oil exists in diploid (12-24%) and tetraploid (13-33%). In general, *Gossypium* species is considered to posses 21 per cent of oil. Cotton seed oil contains 50 per cent of linoleic oil (polyunsaturated fatty acid) which is ideal for human consumption. Every one kg of fibre is obtained from 1.65 kg of seed cotton. By considering the amount of protein present in the seed (23%), global seed cotton yield of 47 million tons could serve as 10.8 million tone proteins, which is more than sufficient to cater the needs of daily protein requirement (50g/day) of nearly 500 million people/year. This is only one impediment in achieveing this nutritional security is the "Gossypol". Gossypol is terpeniod aldehyde compound present in the entire pant plants of Gossypium species including seed. This imposes serious health problems in monogastric animals including humans and impairs protein conservation ratio in ruminants. This warrants a need for developing, gossypol less seed cotton, which comes with premonition of herbivore attack to the plant parts, as gossypol deters most of the herbivore attack. An ideotype concept of glanded plants with glandless seed would be an ideal plant tailoring concept for breeding gossypol less seed.

f) Topic : Acceptability of drudgery reducing technologies in cotton picking,

Speaker : Dr. (Mrs.) Kusum Rana Prof. Extension Education

Directorate of Extension Education, CCSHAU, Hisar

Dr. Rana said that rural women in Haryana are involved in most of the agricultural operations viz., transplanting, weeding, picking and post harvest activities. Cotton picking is a tedious job exclusively handed by women folk in Haryana. During the study time and activity profile, work out and acceptability of the cotton bag was assessed. Women performed picking activity between 50-60 days in a year. The women reported severe pain in palm, wrist, fingers, neck and shoulders. Majority found to be highly accessibility. Overwhelming majority perceived thata using cot bag reduced pain in hands and overall it helped in reducing the drudgery of women to be a considerable extent. Adequate rest pause coupled with training on use of proper body postures alongwith light exercise for back and shoulders are required to delay the onset of fatigue. High accessibility of cot bag among rural moment and its promotion is suggested.

g) Topic : PKV Hy2 BG-II: Successfully commercialized first *Bt* cotton hybrid of public sector in Maharashtra

Speaker : Dr. S.B Deshmukh, Plant Breeder,

Dr. P.K.D.V Akola

Dr. Deshmukh said that India is maintaining leading position in cotton acerage in the world. China is leading in terms of cotton production and United States is ahead in export of cotton. In the productivity Australia is leading followed by China and Brazil. India is way behind productivity. This hybrid PKV Hy2 BG-II is having yield potential and suitable for rainfed conditions and due to density hairy leaves, it is tolerant to major sucking pests. This hybrid is not only popular among farmers of Maharashtra and also cover major to its wider adaptability. But after the introduction of *Bt* cotton technology in 2002, farmers started growing *Bt* cotton hybrids and area under this hybrid was shrunken and replaced by *Bt* cotton hybrids. Rest farmers could not forget the performance of this hybrid and they were continuously demanding *Bt* version of this hybrid. So considering the demands of the farmers, Dr. P.P.K.V Akola and MSSCL, Akola has signed a MOU to convert this hybrid to *Bt* version. Accordingly, a well defined BG-II gene introgession programme in parents of this hybrid was initiated by both organizations. During the course of conversion of parental lines into BG-II version using back cross breeding, the technical support and when required was extended by the University scientist from time to time for the successful development of *Bt* cotton hybrid.

h) Topic : Combining ability based selective hybridization of parental F_1S to develop double crosses in cotton (*gossypium hirsutum* l.)

Speaker : Dr J. M. Nidagundi, Cotton Breeder & Head

AICRP on Cotton UAS Main Agricultural Research Station, Raichur

His study is based to find out specific combiners exhibiting heterosis and also to extract good general combining ability parents for yield, yield attributes and fibre quality traits to isolate transgressive segregants essential for successful breeding programme.

i) Topic : Studies on Heterosis and combining ability analysis in upland cotton (*G. hirsutum* L.)

Speaker : Dr. K. V. Vadodariya, Main Cotton Research Station,

Navsari Agricultural University, Navsari

He said that the parents *viz.,* GSHV 171, NDLH 1928 and GISV 267 exhibited higher seed cotton yield per plant. The highest standard heterosis over both the standard checks as well as the higher heterobeltiosis for seed cotton yield per plant was recorded by the cross GISV 267 x NDLH 1928. Combining ability analysis revealed significant and positive variances due to general combining ability (ó2GCA) for all characters which revealed the importance of additive gene action in inheritance of these characters. Similarly, variances due to specific combining ability (ó2SCA) were observed significant for all the characters except 2.5 per cent span length which showed the role of non-additive gene action in inheritance of these traits. Majority of the characters manifested less than one ó2GCA / ó2SCA ratio indicated that non-additive effects, epistasis and/or dominance played a more significant role than additive effects for inheritance of these characters.

j) Topic : Cotton fibre and yield traits improvement interactive using consensus based QTL hot spot and its trargetted NGS sequencing data.

Speaker : Dr. S. N. Jena,

CSIR-NBRI, Lucknow

Dr. Jena said that cotton is one of the best fibre crops, cultivated world wide with a vast economy. The main focusing on consensus mapping based QTL, hot spots for fibre quality and yield traits and their targeted NGS sequency to characterize the key genes haplotype blocks governing the fibre quality and yield traits. Due to the low rate of polymorphism the consesus map on the other hand, is the right choice of mapping in cotton using more than one mapping population. The fibre quality of five populations at 3 locations for two years will be gathered and the meta analysis of QTL hotspots for the consensus map will be performed with 10 public domain data a meta analysis revealed 50 hotspots which will be further analyze for indentification of combined QTL hotspots of Indian mapping populations with that of the public domain data. In conculsion, we propose a sequence based breeding approach which includes the use of independent or combination of parental selection on the basis of QTL hotspots based haplotype blocks/genes for cotton yield and fibre quality traits.

Technical Session – IV (Oral presentation for Award)

(Concurrent Session : Crop Production, Mechanization and Economic Development)

Venue	:	**Biju Patnaik Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**9:00- 11:30am**
Chairman	:	**Dr. K. K. Rout,** Dean, COA, OUAT
Co-Chairman	:	**Dr. L. M. Garnayak,** Prof. Agronomy, OUAT
Session Co-ordinator	:	**Dr. L. Tripathy,** Assoc. Prof. Floriculture, OUAT
Rapporteurs	:	**Dr. Amarpreet Singh,** Agronomist, CICR, Regl. Station, Sirsa
	:	**Dr. Abhiram Dash,** Asstt. Prof. Agronomy, OUAT
Evaluators	:	**Dr. Samunder Singh,** Prof and Head, Agronomy, CCS HAU, Hisar
	:	**Dr. Lilymeeny Tripathy,** Assoc. Prof. Floriculture, OUAT
	:	**Dr. Debraj Behera,** Prof. & Head, FMP, OUAT

Twenty two lectures were scheduled to be presented as per programme but only thirteen papers were presented.

a) Topic : Seed cotton yield and sucking pest dynamics in American cotton (*Gossypium hirsutum* L.) as affected by genotypes, crop gemetry and nutritional levels under semi-arid conditions.

Speaker : Dr. Kulvir Singh, Agronomist, Cotton

PAU, Regl. Station, Faridkot

Dr. Singh undertaken a field investigation to evaluate the performance of two American cotton cultivars under different plant genometry and nutritional leves at the experimental area of PAU, Regional Station, Faridkot during 2016-2017. Experimental findings revealed that F2228 resulted in significantly higher seed cotton yield over check variety. Nutritional levels failed to exert any significant effect on seed cotton yield. However, among sucking pests, whitefly population was significantly affected at 100 days after sowing and that too far planting geometry and nutritional levels. Study also revealed that higher N application rates resulted into significant increase in whitefly population at 100 DAS. A similar trend was also observed in case of jassid population which was least at lowest rate N application. A planting geometry of 67.5x60 cm, nutritional level of 75:30:50:25 kg of N, P, K and Zn/ha and F2228 has been found to be better option for higher seed cotton yield under semi arid irrigated conditions of noth India. To address the rising fibre needs of the textile sector and global trade demands, cotton production needs to be boosted not only through the inclusion of more area under cotton cultivation but also through focused emphasis on production practices such as plant geometry, nutrient management potential genotypes for improving economic status of cotton growers.

b) Topic : Adoption of drip fertigation for cotton is helping in doubling farmers income

Speaker : Dr. B.D. Jade, Chief Scientist

Jain Irrigation System Ltd., Jalgaon

Dr. Jade said that cotton is very important cash crop growth in India. Though area in cotton under Maharashtra is highest, however the productivity is the lowest. Constraints of low productivity in Maharashtra are lack of irrigation facilities, erratic monsoon, no moisture available in soil at boll development stages in cotton growing area. Most of the cotton in Maharashtra is cultivated as rainfed crop. Maharashtra is a pioneer in adoption of drip irrigation technologies in the country. The farmers have started the adoption of this technology from 1987-1988. Results of pre-monsoon cotton sowing under drip irrigation are amazing. Rainfall do not match with the growing stages of cotton crop due to withdrawl of moonsoon during boll development stages resulted low yields of cotton, drip irrigation maintains field capacity of soil. Water and nutrients are efficiently managed through drip irrigation technology which leads to get bumper yields of cotton. This model is now replicated in Gujarat, M.P., A.P. Yields of cotton have increased 200-300 per cent by adoption of this technology. Farmers yields are increased due to pre-monsoon sowing, hybrid *Bt* varities, drip irrigation and fertigation technologies, soil water plant relationship get maintained under drip irrigation, crop never get water stress at any stage.

c) Topic : Evaluation of high density planting system and fertilizer requirement for hirsutum cotton varieties

Speaker : Dr. S.L. Pawar, Agronomist, Cotton

NAU, Main Cotton Research Station, Surat

Dr. Pawar said that cotton is important commercial crop of India grown for fibre, fuel and edible soil and plays a important role in Indian economy. The research related to increase production is continuing in India through development of new varieties and hybrids including *Bt* cotton, crop production technologies through increase of input use efficiency, better irrigation management practices like drip irrigation and pests and disease management technologies. After a long research, potential genotypes and hybrids alongwith optimum plant population, ideal fertilizer application, crop protection techniques, have played a important role in increasing the cotton seed production in Gujarat and India. Manipulations of planting density, plant population and spartial arrangements of cotton plants countries to be topic of cotton Research world wide.

d) Topic : Cotton production technologies of newly developed hirsutum and arboreum genotypes through HDPS under irrigated condition

Speaker : Dr. R.S. Wagh, Head, Cotton

Cotton Improvement Project, MPKV, Rahuri

Dr. Wagh have said that India has the largest area in the world and is the second largest producer in the world. India's average cotton productivity is 480 lint yield ka/ha combining both irrigated and rainfed fields and this is very low as compared to other countries like China (1726 kg/ha), Brazil (1636 ka/ha) and United States (936 ka/ha) and the world average yield was (779 kg/ha). The ultra narrow row system is very popular in several countries. The availability of compact genotypes, acceptable of weed and pest management technologies including transgenics, development of stripper harvesting machines and wide spread application of growth regulators have made these high density cotton production systems successful in these countries. The another advantage include better light interception, efficient leaf area development and early canopyt closer which will shade out the weeds and reduce their competitionness. The early maturity in soils that do not support excessive vegetative growth can make this system ideal for shallow to medium soil under rainfed conditions, where conventional low maturity hybrids experience terminal drought. Therefore, high planting system is being now conceived as an alternate production system having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input cost and minimizing the risk associated with current cotton production system in India.

e) Topic : Inflence of high density planning system on weed population in cotton (*Gossypium hirsutum* L.)

Speaker : Dr. K.B. Sankat, Agronomist, Cotton

NAU, Main Cotton Research Station, Surat

Dr. Sankat said that cotton is the most important commercial crops in India. To strengthen the economy of the farmers and of the country, it is essesstial to enhance the productivity of this crop which is governed by many factors. Weed management plays a very critical role because wide spacing, initial slow growth, continue rainfall and heavy use of nutrients provide enough room for profuse growth of weeds resulting in critical crop weed competition ultimately in poor seed cotton yield. This competition can be reduced remarkably by adopting suitable weed management measures. Among the agronomic constraints of cotton production, weed infestations have historically been a major issue. Despite many advances in weed management technologies cotton growth still face significant challenges from weeds.

f) Topic : Effect of conservation agriculture and residue management of yield and economics of cotton-maize cropping system

Speaker : Dr. R. Veeraputhiran, Agronomist, Cotton

TNAU, Cotton Research Station, Srivilliputtur

Dr. Veeraputhiran said that cotton is an important fibre cum cash crop of India as well as of Tamil Nadu. Maize queen of cereals is the most versatile crop with wider adoptability is varied agro-ecological conditions and there is a increasing trend is observed in the cultivation of maize and cotton contribute 70 per cent and 17 per cent, respectively. The crop residues which are having enormous value if utilized properly will have great potential for improving soil fertility, creation of pollution free environment besides improving the yield of crops. Conservation agriculture is emerging as a big boost for crop production in India. It is based on minimal soil disturbance, which may have great scope to save labour, time, fuel and machinery wear. The main concept of zero tillage is to avoid prepretory cultivation and without carrying any tillage operations. To manage the crop residue in a productive and profitable manner, conservation agriculture offers a good promise. Development of conservation agriculture based resource conserving technologies which are more resource efficient than conventional method of cultivation is paramount importance for long term sustainability. Thus it is concluded from the study that zero tillage under cotton maize tillage was technically bearable and zero tillage with 100 per cent residue application registered comparable yield of cotton and maize with higher economic benefits and less labour use.

g) Topic : Quantitative relation of crop development and drying with temperature in different *Bt* cotton hybrids

Speaker : Dr. J.A. Patel, Agronomist, Cotton

S.D. Agricultural University, Cotton Research Station, Talod

Dr. Patel said that cotton is one of the most important commercial and industrial crop. It plays a vital role in economical and social affairs of the world and benefit several million people who are engaged in the cultivation, trade, processing and manufacturing. In the recent past "Para wilt" is the burning maja problem of cotton cultivation in north Gujarat. Many assumptions are made for the causes of "Para wilt" like high temperature, high boll load, poor soil fertility etc but question is yet unanswered. The development role of cotton is strongly influenced by temperature. Temperature measurement during the cropping season help estimate when a crop reaches a specific development stage. So it is very important to find out relation between heat received by cotton crop upto harvest and willing. It is reported that when crop produced opened flowers on tree top of the cotton plant is the first signal of crop maturity.

h) Topic : Evaluation of cotton genotypes for seed oil, protein and gossypol contents

Speaker : Dr. H.R. Ramani, Biochemist, Cotton

NAU, Main Cotton Research Station, Surat

Dr. Ramani said that cotton seed oil has long been consideredc to be a good vegetable oil for frying, in part because it tends to impart a toasted aroma to tried products. Cotton seed oil has also disadvantages that have resulted the some food companies limiting their use of the oil. Specifically, the oxidative stability of cotton seed oil can be lower than other vegetable oil because of its high concentration of linoleic acid (18:2). When used for frying, this instability accelerates the formation of off-flavors (rancidity) and shortened oil life. Although the level of these acids is significantly reduced by oil deodorization, they would be fully present in whole seed or kernel feeding of cotton seed to animals, a practice that would increase of current efoorts to reduce seed gossypol levels prove successfully, protein contents and fatty acid profile of cotton seed oil were varies from genotype to genotype. The study was done with 34 genotype to analyzed for oil, gossypol and protein contents. The results showed significant variations amongst the genotypes, However, considerable background information is needed to study the degree of compositional variation that exists in seed oil, gossypol and protein contents of cotton genotypes.

i) Topic : Effect of different sources of nutrients on organic cotton production under rainfed upland ecosystem of Odisha.

Speaker : Dr. B.S. Nayak, Cotton Agronomist

OUAT, Regional Research and Technology Transfer Station, Bhawanipatna

Dr. Nayak said that productivity of cotton in India is far below as compared to global standards. The modern cotton production technologies relie on the heavy use of fertilizers and chemicals to control insect-pests and diseases and weeds. Use of chemicals at such scale leads to science ecological and human hazards, therefore, to protect the environment and maintain the cotton productivity at a sustainable level, organic use of inputs is in evitable organic farming creates rural employment and use of on form resources to market it more cost effective. The beneficial use of farm yard manure, vermicompost, castor cake, green mannuring, use of biofertilizers like Azotobactor and phosphos solublizing bacteria for increasing cotton productivity.

j) Topic : Influence of tillage and weed management practices on cotton green gram cropping system

Speaker : Dr. B.D. Patel, Professor Weed Management

B.A. College of Agriculture, AAU, Anand

Dr. Patel said that cotton is the main *kharif* crop in irrigated middle western plain of Gujarat. Losses in seed cotton yield due to the presence of unwanted plants called weeds. Generally pre-emergence and post-emergence herbicides were used for the control of weeds but it need proper time and skill. The combination of pre and post emergence herbicides is required to be integrated for effective weed management to increase seed cotton yield. For better establishment of crop stand, well polerized seed bed plays on important role. Tillage is considered as most effective and efficient technique for the preparation of seed bed and to control the weeds. Conservation tillage practices are the alternative which accumulates organic matter in the soil surface, enhance water absorption capacity, improve soil physical, biological and chemical properties increased yield after the application of 6-8 years. Similarly there is no tillage in zero tillage, soil be come compact and may restrict growth of roots, which ultimately reduce the cotton yield. Generally before sowing of cotton, seed bed prepared and then application of pre-emergence herbicides are common practice adopted for the control of weeds combination of various tillages viz., zero tillage, conservation tillage, minimum tillage etc. alongwith some promising post emergence herbicide may provide the effective control weeds which help in improving the yield and quality of cotton.

k) Topic : Production performance and market integration of cotton markets in India

Speaker : Dr. Shruti Mohapatra, Asstt. Prof. Economics

Department of Agricultural Economics, OUAT

Dr. Mohapatra said that the present study was undertaken to work out the trend in area, production and productivity of cotton in the country and to analyse the integratia among major cotton markets based on secondary data. The analysis revealed that production and productivity of cotton was consistently increasing significantly over the years at global, country and state levels. India was leading among all the cotton growing countries in the world regarding area under cotton and it was the second largest producer of cotton after China. In the state wise analysis, the increase in production in cotton in A.P. was found to be the highest followed by M.P. and Maharashtra and the lowest was observed in T.N. All the selected cotton markets in the state and country were found to be integrated and exhibited long run relationship with each other. Adilabad market was found to be lead cotton market as it was influenced most of the other selected cotton markets in the country.

l) Topic : Option of rural women regarding face masks to mitigate occupational health problems

Speaker : Dr. (Mrs.) Vivek Singh, Assoc. Prof. Clothing and Textile

Directorate of Extension Education, CCS HAU, Hisar

This lecture was scheduled to be presentend by Dr. (Mrs.) Vivek Singh but due to her absence, this paper was presented by Dr. (Mrs.) Kusum Rana, author of this paper. Dr. Rana said that women share abundant responsibilities and perform a wide spectrum of duties in running her family, maintaining the household, care of domestic animals and attending various form operations. Two types of face masks *i.e.* one pleated mask and another scarf mask were developed by the department of clothing, textile and apparel Designing, College of Home Science, CCS HAU, Hisar to mitigate health problems especially respiratory problems reported by rural women engaged in various household, animal husbandry and farm activities like care of animals, fodder collection, cleaning of animal sheds, transplanting, weeding and harvesting. Porous cotton fabric of dark grey colour was used to stitch these masks scarf masks over head and mouth, nose and neck of workers. They also had high option regarding designs of face masks as they opted that these designs are attractive followed by the opionion that shape and size of the face masks is appropriate and type and colour of the fabric *i.e.* porous cotton fabric of dark grey colour used to stich face masks is suitable. The workers found that these face masks are functional.

m) Topic : Effect of methods of gap filling on the productivity of hybrid *Bt* cotton

Speaker : Dr. Amarpreet Singh, Scientist

CICR, Regional Station, Sirsa

Dr. Singh pointed out that cotton is one of the most important fibre and cash crop of India. It plays a vital role in the rural, national and international economy. Highly vulnerable and extreme climatic conditions in North India *i.e.* high temperature, rains and hot winds during sowing and seeding stage in May and June often results in poor plant stand in some of the fields and require re-sowing hence technology to maintain proper plant stand of *Bt* cotton hybrids needs to be evolved. Among the methods of gap filling, growth and yield attribute as well as seed cotton yield was significantly higher under control treatment *i.e.* control with normal plant population at initial actual sowing and there was significant reduction in all parameters under all other treatments. Thus gap filling using inherent moisture can be a better option for gap filling among the tested methods of gap filling if the plant stand is poor with the initial sowing.

Technical Session – IV (Oral Presentation for Award)

Concurrent Session : (Crop Protection and Biosafety)

Venue	:	**Ramaiah Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**9:00- 11:30am**
Chairman	:	**Dr. D. Monga,** Head, CICR Regl. Sation, Sirsa
Co-Chairman	:	**Dr. L.N. Mohapatra,** Prof. Entomology, OUAT
Session Co-ordinator	:	**Dr. Arabinda Dhal,** AICRP on Foreges, OUAT
Rapporteurs	:	**Dr. Abhijit Kar,** Asstt. Prof. Entomology, OUAT.
	:	**Dr. G.R. Bhanderi,** Asstt. Res. Scientist, MCRS, Surat
Evaluators	:	**Dr. Mihir Mishra,** Prof. Plant Pathology, OUAT
		Dr. L.K. Rath, Prof. Entomology, OUAT
		Dr. Rishi Kumar, Principal Scientist, Entomology, CICR, Regl. Station, Sirsa

Ten papers were scheduled in this session of plant protection and biosafety but only six papers were presented.

a) Topic : Radiation technology (SIT) for the management of cotton pink bollworm, *Pectinophora gossypiella* (Sanuders) (Lepidoptera Gelechiidae) as an integral component of cotton IDM,

Speaker : Dr. S.G. Hanichinal, Scientist, Entomology,

Department of Entomology, UAS, Raichur

Dr. Hanichinal said that radibiological investigations were carried out to select on appropriate dose to be employed for sterile insect technique in pink bollworm. The fecundity was significantly decreased with increasing irradiations dose and treated males when mated with normal females laid fewer eggs than two other crosses. The decrease in per cent egg hatch and increase in per cent sterility induced by gamma irraditions were found to be positively correlated with the dose level in all the three crosses than control. Complete sterility was achieved when three day old pupae treated with higher gamma radiation dose. He also said that cotton production was remained stagnant over the year owing to many biotic and abiotic constraints making it uneconomical even world over so far. Among the biotic problems, insect are the major ones in India. Recently cotton pest scenario has witnessed considerable changes in southern part of India and also in cotton growing area of north Karnataka. The outbreak of pink bollworm cause major threat to cotton production in the area. Pink bollworm has progressively increased its activity and develop resistance to cry proteins in *Bt* cotton steady increase in its incidence in the later stages of the crop reducing the lint yield and leading to low quality lint. Pink bollworm incidence goes unnotices to the formed since the young larvae enter the cotton boll in the developing stage.

b) Topic : Biorational management of *Pectinophora gossypiella* in *Bt* Cotton,

Speaker : Dr. K.N. Jawanjal, Scientist, Entomology,

Cotton Research Unit, Dr. P.D.K.V. Akola

Dr. Jawanjal said that cotton is one of the most important crop producing natural fibre which has been under commercial cultivation for domestic consumption and export needs of about 111 countries in the world. Major constraints in attaining of high production of seed cotton is the damage inflicted by insect pests. Insect pest problem in agriculture have shown a considerable shift during first decade of twenty first centuary due to ecosystem and technological changes. Among the insect-pests of economic importance, now a days, pink bollworm is the most important and have been reported to cause serious quantitative and qualitative losses in *Bt* cotton crop. Pink bollworm is the most serious pests of cotton worldwide and causes looses both in yield and quality of cotton. It is distructed in all cotton growing states of the country and has caused million of rupees of damage during the last 3-4 years. From the data overall it was concluded that weekly destructor of rosettee flowers followed by 5 releases of tricholards @3 cords/ac alternated by 4 sprays of Azadirachtiri @10ml/10L at 10 days interval started at 50 DAE provided maximum protection from pink bollworm damage in *Bt* cotton.

c) Topic : Relationship of weather parameters with population of pink bollworm (*Pectinophora gossypiella*) in cotton,

Speaker : Dr. P. R. Zanwar, Prof. and Head,

Entomology, Department of Entomology, VNMKU, Parbhani

Dr. Zanwar said that cotton in the most important crop producing natural fibre which has been under commercial cultivation for domestic consumption and export needs of about 111 countries in the world, hence called **"King of Fibre"** or **"White Gold"**. India is an important grower of cotton on a global scale. The crop is attached by 1326 species of insect-pests throughout the world, of which about 130 different species of insect-pests and mites found to devour cotton at different stages of crop growth in India. The major threat to the continued success of *Bt* crops is evolution of resistance by pests. While most targeted pest populations remain susceptible, resistance to *Bt* crops has been reported in one of the most devasting pests of cotton globally recently, the pink boll worm.

d) Topic : Biosynthesis of green zinc nanoparticles and its effect on sucking pests of *Bt* cotton,

Speaker : Dr. Pavitra, Research Scholar,

Department of Agricultural Entomology, UAS, Raichur

This paper was to be presented by Pavitra but due to her absence Dr. N. Sushila, the co-author has presenting the paper. Dr. Sushila said that *Bt* cotton is genetically modified cotton plant in which cry 1 AC gene from *Baccillus thuringiensis* (a common soil bacterium) is introduced through genetic engineering. The target insect for cry 1 Ac toxin protein have been lepidopteran pest like *Helicoverpa* species and not the sucking pests, which also cause considerable damage in cotton and need to be managed through insecticides. The sucking pests have become a serious problem in *Bt* cotton. These pests not only cause direct losses to the crop but also an increase in number of sprays that lead resurgence of minor pests and elimination of natural enemies. Cotton aphids are the most serious pests of cotton all over the world. Cotton aphids feeding can stimulate foliar allivnations, delay of plant growth, fewer fruit setting, lower fruit rentention and reduced cotton fruit setting, lower fruit retention and reduced cotton lint weight. Among the several avenues to overcome the insecticidal resistance problem, replacement of new molecules of insecticides is one of the important considerations. There is a limited information on use of green nano particle for cotton aphid and mealybua.

e) Topic : Sudden wilt in cotton : Prominent factors countributing to its occurrence in north India

Speaker : Dr. S.K. Sain, Scientist, Entomology

CICR, Regional Station, Sirsa

Dr. Said told that occurrence of sudden wilt problem in cotton in north India is increasing since last one decade. It has been established that para wilt/sudden wilt is a physiological disorder in which the soil plant atmosphere continum is broken due to adverse enviornmental factors like soil saturation which results in poor root growth, and reducing oxygen influx as a principal cause of injury of roots and shoots. However, the studies on primary factors responsible for sudden wilt, situations fields are merely available. The cotton fields where farmers have adopted crop rotations, crop residue incorporation, deep ploughing, timely irrigation resulted better crop with deep rooted system the sudden wilt symptoms were not observed. Sudden wilting situations was more prominent in early maturing and high yielding *Bt* cotton hybrid during first fornight of September.

f) Topic : Efficacy of Insecticides against sucking pests of Cotton

Speaker : Dr. N. Mandi, Entomologist, Cotton

AICCIP on Cotton, RRTTS, OUAT, Bhawanipatna

Dr. Mandi said that cotton in grown as commercial crop in western and southern part of Odisha under upland rainfed conditions. The productivity of cotton in the state is less as compared to the national average of 502 kg lint/ha and this due to higher incidence of sucking pests. Further, due to its extensive cultivation as a mono culture crop, it is attacked by many chewing and sucking insects. Among the sucking pests, aphid, jassids, thrips and whitefly are the major pests of cotton. These sucking pests are noticed at all the stages of crop growth and are responsible of direct and indirect losses of cotton yield. Regular and indiscriminate use of chemical insecticides and the misuse of synthetic pyrothriods on the crop have led to the development of insecticide resistance in target pests, pest resurgence and secondary pests outbreaks, loss of biodiversity, environmental pollution and residual toxicity and occurrence of human health hazards. However, is the present day context chemical control has its own popularity over the other methods of pest control due to its immediate action and remarkable pest control. There is a scope of utilizing newer molecules such as Pyridincarboxamide and Neonicotinoids which are required in small quantities and give economically effective control of sucking pests in cotton ecosystem.

Technical Session – V (Young Scientist Merit Academic Award)

Venue	:	**M. S. Swaminathan Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**12.00 to 14.00 pm**
Chairman	:	**Dr. A. Sarada Devi,** Former Dean Home Science, ANGRAU, Hyderabad
Co-Chairman	:	**Dr. Samunder Singh,** Prof. & Head, Agronomy, CCS HAU, Hisar
Session Co-ordinator	:	**Dr. (Mrs.) Sarbani Das,** Asst. Prof. Ext. Edu., OUAT
Rapporteurs	:	**Dr. Pyavasini Behera,** Asstt. Prof., OUAT
		Dr. (Mrs.) Kusum Rana, Prof. Ext. Edu., CCS HAU, Hisar
Evaluators	:	**Dr. S. S. Patil,** Former Director of Research, UAS, Dharwad
		Dr. S. Usha Rani, Principal Scientist (Extension), CICR, Coimbatore
		Dr. S. Manickam, Principal Scientist (Breeding), CICR, Coimbatore

Nine award papers were listed int he schedule but only six papers were presented

a) Topic : Response of *Bt* cotton (*Gossypium hirsutm* L.) to seed treatment and foliar application of Nano zinc

Speaker : Dr. N. Pruthuvi Raj

Department of Agronomy, UAS, Dharwad

Dr. Raj said that cotton production, processing and trade provide livelihood and employment to several million people. Cotton is a tropical and subtropical crop. A part from major nutrients, micronutrients also play a vital role in cotton production zinc is a essential micronutrient for human, animals and plant. Plant absob zinc in the form of Zn^{+2}. Zinc is immobile in the soil and needs to be either mixed through the root zones or sprayed on the leaf to supply plant available zinc. This can be done through in corporation of surface applied zinc, in furrow injection or a foliar spray. To achieve thus seed treatment and foliar application of micronutrients are the major soils. Due to the significance of zinc element in crop growth and production and thei effective role in increasing yield and quality due to the application of nano form through seed treatment and foliar spray to the cotton crop. The studies related to seed treatment and foliar spray of nano Zno an cotton in India is very meager. Different foliar spray concentrations with chelated $ZnSo_4$ seed treatment did not affect seed cotton yield significantly. Nano coating seeds using elements forms of Zn, Mn and Aq will not only protect seed but also provided immane power to resistant for drought and to some extent the pathogens. The nano particles as fertilizers polantiaty benefit uptake system. They are highly dispersible and have high water absorbing properties. Therefore, nano fertilizers can increase the efficiency of nutrient uptake which improve yield and nutrient content in the edible pats of the plants.

b) Topic : Effect of sewage sludge and inorganic fertilizers on productivity and fertility of soil under cotton wheat cropping system

Speaker : Dr. Sandeep Bedwal

Department of Soil Science, CCS HAU, Hisar

Dr. Bedwal expressed that cotton (*Gossypium hirsutum* L.) and wheat (*Triticum questivum* L.) in Indian sub continent particalavy in north western plants of India is a forely well established croping system since long and it is highly remenerative for the generation of assured income and thus ensures food and financial security o farmers in this region. This cropping sequence has high requirements for nutrients and may adverly affect soil fertility in long run if adequate managment options are not adopted. As in modern agriculture, no single source of plant nutrients can sustain the soil producitivity rather they need to be used in a coherent manner following a managment technology rather they need to be used in a economically profitable and ecologically sou.d Become of the positive effects of organic manures and at the same time every increasing cost of fertilizers and their limited availability, the combined use of organic manures and chemical fertilizers is again regaining importance in crop produciton as well as for the maintence of soil productivity. In this respect, the use of treated sewage sludge as an organic source is an imperative tool that is of increasing interest of farmers and governmental bodies due to its over production and higher nutrient content.

c) Topic : Yield, nutrients uptake and post harved available nutrients in soil by inegrated nutrient management practices

Speaker :Dr. Deepak Kochar

Department of Soil Science, CCS HAU, Hisar

Dr. Kochar said that cotton is one of the world's leading agriculture crop. It is the most widespread profitable non food crop in the world. It is a multipurpose crop that produces lent (fibre), oil, seed meal and hulls. Cotton plant being a heavy feedr, needs proper supply of nutrients for the successive cultivation of cotton. To cater the uptake need of this crop, soil reserves along are not sufficient, hence need to supply them through chemical fertilizers. Among plant nutrients, N plays a key role in crop producivity and it is regarded as growth and yield determinant in irrigated cotton.

Low efficiency of nitrogen applied to soil is major problem of farmers. Nitrogen was subject to teaching, denitretication and volatilization losses, which made it unavailable to crop. Therefore, it is essential to introduce such fertilizer practices as would ensure maximum efficiency of applied nitrogen and these relate to placement, split aplication, appropriale rates and use of nitripication inhibitors for *Bt* cotton. The understand this a study the effect of integrated management in *Bt* cotton for suitaining yield, uptake and fertility status of soil.

d) Topic ; Topic High density planting is viable alternative for rainfed coton production

Speaker : Dr. B. B. Nayak

ANGRAU, Regl. Agril. Research Station, Guntur

Dr. Nayak said that cotton is the most important fibre as well as commercial crop of India and AP. It presumes importance in agriculture as well as industrial economy. Cotton occuption a major share among cash cops as it supports a large section of farming community as well as it provides raw material to textile industries. Commercially, cotton is the best export earning commodity in the country. Among the various factors responsible for low yield of cotton, low plant population and use of low potential varieties are of primary importance. Various agronomic interventions like maintainng suitable plant densties, use of optimum dose of fertilizers, gowth regulators are being used to overcome these curtainments in cotton production. High density plant system (HDPS) is now being considered as an alternative production system having potential for improving the productivity and profitability of cotton. Increasing in put use efficiency, reducing in put cost and minimizing the risks associated with current cotton production sytem in India in the main objectives of high density planting system.

e) Topic : AMMI stability analysis for seed cotton yield in cotton (*Gossypium hirsutum* L.)

Speaker : Dr. A. B. M. Sirisha

Department of Genetics and Plant Breeding

ANGRAU, College of Agriculture, Bapatla

Dr. Sirisha expressed that genotype x environment (GXE) intractions are the major concern of plant breeders. Cotton is the primary source of natural fibre of world is the life line of the textile industry of lead developed, developing and developed nations. Among the cotton species, *G. hirsutum* is highly cultivated for tis quality and yield. Heterosis is exploited for the first time in cotton in India to provide hybrids and *intra hirsutum* hybrids are more common in the cotton growing areas of the country. The hybrids development using diverse parents, evaluation of these crosses and stable genotypes indentification from the imported objectives in cotton breeding. Targeted breeding efforts in cotton have come with undreds of varities/hybrids but the sustainble cotton breeding requires stable genotypes. Thus, stable genotypes indentification is crucial in the cotton breeding to overcome the GXE interactions and to get the desired as thus recues the association between phenotypes and genotypes and suppeses the expression of real capacity of genotype.

f) Topic : Suitability of different tillage systems over conventioned tillage for cotton production

Speaker : Dr. Harjeet Singh Brar

PAU, Regional Research Station, Bathinda

Dr. Brar expressed that presently, cotton is considered on exclusively mechnozied crop in term of tillage operations. Conventional tillage for cotton production involves use of disc harrow, cultivator followed by planting to smooth out the seed bed and intercultural operations for weed control. Cost of cultivation has increased with the intensive use of heavy machinery to proterm different field operations especially tillage. Cost associated with conventional tillage operations include fuel, labour, equipment and maintenance are higher than conservation and no tillage system. Intensive use of heavy machinery for different field opeations is not only increase the cost of cultivation but also deterioate soil physical conditons by soil compactness, resulting tin decline the productivity. Although, different tillage systems have different agronomic benefits but continuous tillage to the same depth increase the problem of soil compactness. Cotton seed beings are easly affected by soil conditons. Soil compactness reduces the oxygen supply and prevents seeds from germinating. There is a polential to cotton production costs and improve the sustainbility of cotton production system by reducing the number of operations in conventional tillage under north zone of India.

Technical Session – VI (Invited Lectures)

Venue	:	**M. S. Swaminathan Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**15.00 to 16.30 pm**
Chairman	:	**Dr. R.S. Sangwan,** Head, Cotton Section, CCS HAU, Hisar
Co-Chairman	:	**Dr. S. Manickam,** Principal Scientist, Breeding, CICR, Regl. Station, Coimbatore
Session Co-ordinator	:	**Dr. Dipika Sahoo,** Assoc. Prof., Horticulture, OUAT
Rapporteurs	:	**Dr. B.S. Nayak,** Scientist Agronomy, AICCIP, OUAT
		Dr. B. B. Nayak, Scientist, RARS, Guntur

Six papers were listed in the schedule but only three papers were presented :

a) Topic : ELS cotton status and strategies for enhancing production

Speaker : Dr. K. Sankaranarayaanan, Principal Scientist, Agronomy**,**

CICR, Regional Station, Coimbatore

Dr. Sankaranarayanan said that *Gossypium barbadence* L. is primarily known as Egyptian cotton or ELS grown primarily in Egypt, Suda and CIS countries ELS cotton is generally used to manufacture high quality ring spun yarns. ELS cotton fibres are stronger and finer than upland cotton fibres Although there are clear cut genetic differences between the two cotton species, the differences are often blurred by dissimilar cotton classification techniques in ELS production countries. The current method of estimating ELS production, consumption and trade is to identify cotton type that are generally longer than upland varieties and report the entire crop of that type as ELS. This techniques allow ELS to be described by type. The leading importer of ELS cotton is Japan, followed by Italy and Germany. All along India has been the pioneer in producing fine and superfine count yarns and has a dominent share in the global textile trade in these varieties. In order to sustain in the global competitions, it is essential to make the cotton available to the mills *on par* with our competitors. Therefore, it has become essential for India to give priority for increasing the ELS cotton production to retain the market share and also to improve the income of the farming community. During the last few years, China and Pakistan have entered into the market using the imported cotton particular from USA and Egypt and have become the competitors for India.

b) Topic : Implications of management strategies on whitefly *Bemisia tabaci* Gennadius (Hemiptera : Aleyrodidae) dynamics and susceptibility to commonly used insecticides in north cotton growing zone of India

Speaker : Dr. Rishi Kumar, Principal Scientist, Entomology,

CICR, Regl. Station, Sirsa

Dr. Rishi said that whitefly is an important polyphagous and invasive pest. In north zone cotton growing areas of India whitefly dynamics showed increasing infestations since 2012 leading to severe outbreak of whitefly in 2015-2016. The main causes of whitefly outbreak were use of susceptible hybrids, having or bushes genotypes, late sowing, application of nitrogenous fertilizers, inadequate phosphorus and potassium in the soil, improper choice of control measures, faulty methods of insecticides applications, and development of resistance in whitefly against insecticides. Among the several human interventions reported to be responsible for the outbreak, changes in the sustability of whitefly to commonly used insecticides was considered very important and need to be investigated further. The management practices adopted helped in reducing the incidence of whitefly inspite of favourable conditions of whitefly after 2015-2016 season especially during 2017-2018. Among these, resistance to insecticides in insect was adjudges one of the serious factors. The pesticide use pattern, insect incidence and crop management practices and availability of other alternate hosts in the north zone influenced resistance development. To strengthen the management strategies, studies on whitefly dynamics under unprotected conditions were conducted alongwith resistance monitoring to document variability in population responses to commonly used and new insecticides.

c) Topic : Extension strategies to reduce the yield and knowledge gap in cotton

Speaker : Dr. (Mrs.) S. Usha Rani, Principal Scientist, Extension,

CICR, Regl. Station, Coimbatore

Dr. Usha have said that cotton yields are stagnated for the past few years due to various factors. Cotton research system has released many technologies to improve the yield under various conditions, but there is always gap between the potentital yield of the technologies claimed by technology inventors and the actual yield realized by the farmers in the field so there are possibilities of bring the gap in cotton yield by properly identifying the causes of gap, appropriate management options to close the gap, fitting Transfer of Technology (TOT) innovations to reduce the gaps an extension study was conducted. Similarly, it is found that through FLD like TOT interventions, we can reduce the yield gap between world average and Indian average to a tune of 49 per cent. Considering the result, extension strategies which can reduce the knowledge gap and thereby the yield gap between world average and Indian average to a tune of more than 50 per cent are explored.

Technical Session – VII (Poster Presentation)

Venue	:	**In front of M. S. Swaminathan Hall**
Date	:	**Thursday, 23rd January, 2020**
Time	:	**17.00 to 18.00 pm**
Evaluators	:	**Dr. P. Nalyini,** Principal Scientist, CICR, RS, Coimbatore
		Dr. D.B. Deosarkar, Dean, VNMKV, COA, Parbhani
		Dr. K. Sankarayanan, Principal Scientist, CICR, RS, ...

There were three categories where the scientists have submitted their papers for Poster Presentation were :

a) Crop Improvement, Biotechnology and Post Harvest Technology

b) Crop Production and Mechanization

c) Crop Protection and Biosafety

In total 98 posters were presented in different categories *i.e.* in a(32); b(39) and c(27). The scientists were present to discuss their results with the evaluators team.

In the first category the main topics were on stability analysis, heterosis studies, genetic variability, interspecific hybridization, coloured cotton, development ELS, combining ability, association analysis, multivariate analysis, PCR based molecular markers, DUS characterization, fibre and yield traits, In the second category the main topics were sewage sludge, inorganic fertilizers, different tillage system, productivity and economic sustainability, different tillage system, productivity and economic sustainability, management of leaf reddening, drip fertigation, weed management, nutrient uptake, post harvest available nutrients, integrated nutrient management, water use efficiency, nutrient requirements, high density planting system, canopy management, liquid microbial inoculants site specific nutrient management, conservation agriculture, residue management, soil fertility status, date of sowing, preliminary agronomic evaluation, moisture stress management, planting density, nitrogen management, altered sowing dates, instability in cotton production, inter cropping crop diversification, labour saving technology, cotton trade, economics of major cash crops, acceptability of cotton bag. In the third category the major topics where in the scientists have tried to explain the status of this category *i.e.* collection, isolation and characterization, evaluation of fungicides, efficacy of insecticides, bioefficacy of newer insecticides, incidence of pests, status of CLCuV, dynamics of major pests, biorational management, IDM modules, seasonal incidence, weather correlation in pest incidence, validation of IRM/IPM, yield losses, natural enemies, sudden wilt, different fungicides, fall armyworm, constraints and suggestions, manipulations of source shik relationship, mitigate health problems, gene silencing etc.

The scientists presented their posters with nice photograph, histograms, graphs, news paper clippings, tabular form. The team visited each and every poster and discussed with the scientist presenting his work. Majority of the scientists were present before their posters to explain to the visiting team. The team praised that the posters were of good quality and the scientists have worked hard to express their results in different methods of presentations. A few posters were not represented by the scientists to reply the querries and to explain their results.

Technical Session-VIII (Lead Lectures)

Venue	:	**M.S. Swaminathan Hall**
Date	:	**Friday, 24th January, 2020**
Time	:	**9.30-11.30**
Chairman	:	**Dr. K. Sankarayanarayana,** CICR, Regl. Station, Coimbatore
		Dr. S. Usha Rani, Principal Scientist, CICR, Regl. Station, Coimbatore
Session Co-ordinator	:	**Dr. Sarbani Das,** Asstt. Prof. Ext. Edu., OUAT
Reporteurs	:	**Dr. N.K. Yadav,** Scientist, CCS HAU, CRS, Sirsa
		Dr. Deepa Kulbe, Asstt. Prof. Plant Pathology, OUAT

Eight lectures were listed in the schedule of lectures but only five lectures were delivered by respective speakers.

a) Topic : Targeted approach through molecular breeding in cotton for increasing productivity in cotton

Speaker : Dr. I.S. Katageri, Assoc. Dean,

UAS, College of Forestry, Sirsi

Dr. Katageri said that selection or hybridization programme to develop varieties/hybrids is the essential of plant breeding. Phenotype based selection is deceiving due to involvement of non heritable genetic components and enviornmental effects. In order to truly predict genotypic values and put them into breeding programme, there is a need to understand underlaying genetics mechanism and apply them based on the changing climate and human needs. It is one of the succesful stories of targetted improvement activities like *Bt* cotton introduction brought double yield level. Although cotton breeding in India has seen so many improvement, still there is a huge scope for yield enhancement as Indian productivity is lower than worlds average, countries like Australia and Brazil have triple yield levels than India which enjoy congenial climatic conditions of cotton growth. The factors such as weed, drought and sucking pests can bring upto 50 per yield reduction which can be addressed. India is a leading producer in the world by virtue of larger acereage and we export the medium and long staple cotton to other countries, but India also imports extra long staple cotton. The genomic resources developed or developing in cotton has also the capacity for avoiding such a losses and bring our yield and quality levels on par with other countries.

b) Topic : Cotton Leaf Curl disease - Lession Learnt and the way forward

Speaker : Dr. D. Monga, Head,

CICR Regl. Station, Sirsa

Dr. Monga reported that cotton leaf curl virus disease was first noticed in Nigeria and in neighbour countries Pakistan in 1967 from which it has assumed to have spread to India on *G. hirsutum* near Sriganganagar in Rajasthan through the vector whitefly. The subsequently its appearance in patches around Sriganganagar district of Rajasthan on *G. hirsutum* in 1993, and presently it is restricted north zone of India. Cotton leaf curl virus disease is caused bya complex of whitefly from nutted Begomoviruses having mono partilite genome with circular ssDNA associated with satellite (beta and alpha satellite) DNA molecules Begomoviruses are mergent pathogen widely distributed in tropical, subtropical and temperate regions world wide and are serious threat to important crops. The infectious clones of the monopartile begomovirus cotton leaf curl virus (CLUuV) associated with diseased cotton, are unable to induced typical symptoms in host plants. The third component of begomovirus betasatellite complexes were the alpha sattellites. Alpha satellites were not true satellites, as they were capable of autonomous replication, and were described as satellite like. The CLCuV/DNA beta/alpha satellite complex, represent members of an entirely new type of infectious disease causing agents.

c) Topic : Yield improvement in rainfed cotton through new plant type concepts - a perspective

Speaker : Dr. Ramesh Thatikunta, Assoc. Dean,

College of Agriculture, Warangal

Dr. Ramesh said that Mongol-tartar dynasti, brought cotton to China from India in the thirteeth Century presently India is the largest cotton producer of cotton due to more acreage. Though China having only half the area under cotton production as compared to India, could be able to produce one and a half times more cotton, with one and a half times the global market share and three times more yield as compared to India. Cultivation of cotton is continued to the 60 per cent of rainfed areas that are characterized by shallow soils, where uncertain monsoon and deficit rainfall prevails more frequently. This is resulting to low productivity due to negative effects of low soil moisture on boll formation and retention. Cotton production is becoming less attractive, but area is increasing since it is grown mostly on rainfed condition where there is no alternative crop better than cotton productivity has to be improved in these light soils which show low moisture tention capacity by developing short compact type genotypes with early maturing that suit high density planting system. Advantage of HDPS is earlyness with high plant population with less bolls/plant that paves way for high yield than conventional cotton.

d) Topic : Fiber quality improvement - Indian perspective

Speaker : Dr. S. Manickam, Principal Scientist,

Breeding, CICR Regl. Station, Coimbatore

Dr. Manickam said that since independence, there was a drastic change in both quality and quantity of cotton production in India. At the time of independence, mostly short and medium staple cottons were produced. Today India produces the widest range of cotton from 6-120 counts from non-spinnable coarse to medium long, extra long and super fine cotton currently, the long and extra long staple cotton production is more than 75 per cent of total cotton production, which was only 17 per cent before the establishment of AICRP on cotton in the country. This is mainly due to the concerted efforts of cotton breeders who developed high yielding long and extra long staple cotton varieties and hybrids suitable to different agro ecosystem of the country. The cotton productivity has been enhanced remarkably especially after the establishment of AICRP on cotton. Ideally the textile mills look for suitable combination of staple length, micronaire and strength for spinning yarn of appropriate quality and more emphasis was given to the improvement of yield as well as quality in cotton, which led to the quantum increase in the production of long and extra long staple cotton in India.

e) Topic : Centre of Excellence : A Vision

Speaker : Dr. P.P. Shastry, Dean,

College of Agriculture, Khandwa

Dr. Shastry emphasized that organic seed is a crucial link in the chain from research breeding and seed production to organic production. The aim is to provide the growers with appropriate and healthy seeds at a reasonable price with organic seed the grower complete the chain with organic inputs for seed producers organic seed is the start for selecting and breeding appropriate organic varieties. Professional organic growers are making high demands on the quality of seeds. Compared to conventional seed production there are several aspects that deserves extra attention. Since no treatment both chemicals is possible to control diseases and pests, it is important to find the optimal climate for a favourable development of the seed crop. For the same reason it can be a solution to find a region where the crop is not grown widely. Diseases and pests are then prevented because infection is unlikely. Depending the crop or species, a wide range of cultivation methods can be developed to improve seed production for example, like planting in a wider spacing for drier microclimate in the crop, drip irrigation instead of flood irrigation over the crop, moderate fertilization to stimulate a generative plant development when diseases and pests appear they can be treated with biological pesticides or predators, seeds transmissioned diseases are a serious problems, since disinfection afterwards is often impossible when seeds are nevertheless infected, disinfection of the seeds is in some cases possible and effective by warm water treatment.

Valedictory and Plennery Function

Date	:	**Friday, 24th January, 2020**
Venue	:	**M.S. Swaminathan Hall**
Time	:	**12.00 - 14.00**
Chairman	:	**Dr. D.P. Rai -** Former Vice-Chancellor, OUAT
Co-Chairman	:	**Dr. P.K. Agrawal,** Vice Chancellor, OUAT
		Dr. K.K. Rout, Dean**,** College of Agriculture, OUAT
Guest of Honour	:	**Dr. S. S. Siwach,** President, CRDA, CCS HAU, Hisar
		Dr. M.S. Chauhan, Secretary, CRDA, CCS HAU, Hisar
Session Co-ordinator	:	**Arabinda Dhal, O/C,** AICRI Pan Forage, OUAT
Rapporteurs	:	**Dr. B.H. Oshamani,** UAS, Raichur
		Dr. Iswar Mohanty, Prof. Biotechnology, OUAT

At the outset Dr. K.K. Rout, Dean, College of Agriculture, OUAT welcome the dignitaries on the dias, delegates, members of the organizing committee and guests. Session Chairman/co-chairman presented the reports proceedings and recommandation of their sessions. There was some discussions on some of the points and also on recommondations. The chairman agreed to these suggestions and assured them that their view points will definately be taken care of while making the final recommondations, Dr. S.S. Siwach praised the CRDA and OUAT team for nice organization of the National Symposium and advised the research workers to concentrate both on basic and applied research to promote cotton to make these crops remunerative. Dr. K.K. Rout also thanked the CRDA team and particularly to Dr. M.S. Chauhan, the man behind the show and said that Dr. Chauhan at this age had visited OUAT 3-4 times to monitor each and every arrangement and some suggestions for further improvement. He said that Dr. R.K. Patniak and Dr. Chauhan were very comfortable with each other throughout the event. He also said that Dr. Patniak took an advantage of Dr. Chauhan's experience of organizing 12 national/International conference/congress/symposia at different places in the collaboration of SAU's and ICAR. Dr. P.K. Agrawal also praised the congenial atmosphere during the national symposium and the credit goes to the entire team of CRDA and OUAT and especially to Dr. M.S. Chauhan. He presented the momentos to the entire team of OUAT with the courtesy of CRDA. Dr. Rai, the former Vice-Chancellor of OUAT also welcome the delegates and said that they have come from far far places to present their work. He said that the organizers should be thankful to these delegates without which the success of this national symposium was not possible.

He also said that now you are working in the 21st Century and modernization of methodology, working and analysis methods have changed and you are to adjust yourself with these changes. He presented the certificates and momento to the winner of Young Scientist Academic Award, Best Poster Award for all three categories, Best Oral Presentation Award to different categories. The CRDA presented momento and said to Dr. Rai, the Chairman of the closing function and to all dignitries on the dias. Dr. R.S. Sangwan was also honoured with momento and shawl for dedicated service to CRDA on different positions and hope he will render his service after his retirement. Dr. Patniak proposed formal vote of thanks. He particularly thank ICAR, CRDA for giving the opportunityto organize this event of OUAT, Bhubaneswar the city of temples. He also thanked the delegates and participants for presenting their good research work and also participating the discussions where ever necessary. Finally he thank all the persons who were directly or indirectly associated with the organize part of this National Symposium. The symposium ended with "National Anthem" and thanks to the Chair.

I. Young Scientist Academic Award

Author : N. Pruthvi Raj and C.P. Chandrashekara

Department of Agronomy,

University of Agricultural Science, Dharwad

Topic : Response of *Bt* cotton (*Gossypium hirsutum* L.) to seed treatment and foliar application of Nano Zinc

II. Best Posters Award

a) Crop Improvement, Biotechnology and Post Harvest Technology

Author : A.B.M. Sirisha, Lal Ahmed M., P.V. Rama Kumar, S. Ratna Kumar and V. Srinivasa Rao

Department of Genetics and Plant Breeding

ANGRAU, College of Agriculture, Bapatla

Topic : AMMI stability analysis for seed cotton yield/plant in upland cotton

b) Crop Production and Mechanization

Author : K. Sankaranarayanan, A.H. Prakash, A. Manivannan and M. Sabesh

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

Topic : Identification of soil parameters influencing yield and fibre quality in ELS cotton.

c) Crop Protection and Biosafety

Author : G.R. Bhanderi, R.D. Patel, H.R. Desai and R.K. Patel

Navsari Agricultural University, Main Cotton Research Station, Surat

Topic : Assessment of yield losses due to mealybug (*Phenaccocus solenopsis* Tinsley) infestation in the cotton farmers fields of south Gujarat

III. Best Oral Presentation Award

a) Crop Improvement, Biotechnology and Post Harvest Technology

Author : Dharminder Pathak, Pankaj Rathore, Harish Kumar and Suruchi Vij

Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana

Topic : Utilizing secondary gene pool for enhancing trait value in cotton

b) Crop Production and Mechanization

Author : B.D. Patel, D.D. Chaudhari, V.J. Patel and H.K. Patel

AICRP - Weed Managment, B.A. College of Agriculture, Anand Agricultural University, Anand

Topic : Influence of tillage and weed management practices on Cotton green gram cropping system.

c) Crop Protection and Biosafety

Author : Pavitra, N. Sushila, A.G. Sreenivas, J. Ashoka and H. Sharanagouda

Department of Agricultural Entomology, University of Agricultural Sciences, Raichur

Topic : Biosynthesis of green zinc nanoparticles and its effect on sucking pests of *Bt* Cotton.

Recommendations of National Symposium

- Focus on important natural fibers other than cotton for higher export potential
- Value addition can be done by blending different fibers of different origins
- Riba-50 may be used as the resistance source against bacterial blight of cotton
- Microniare value for the developed lines may be improved
- Intercropping technique is already available which can be readily used for the state of Haryana
- Organic cotton cultivation in India may be promoted
- Seed dye extracted from *Bixaorellana* may be promoted
- The use of growth promoters like jasmonic and salicylic should be encouraged in *Bt* cotton
- Efficient Entomopathogenic Fungi (EPFs) compatible with chemicals provide an alternate option for IPM/IRM for whitefly
- Manual weeding, pre-emergence use of pendimethalin 1.0 kg/ha (PRE) *fb* hoeing *fb*quizalfop/ propaquizafop 60 g/ha or pendimethalin 1.0 kg/ha (PRE) *fb* protected spray of glyphosate (0.5%) at 60 DAS can be adopted for controlling weeds
- Most of the *Bt* cotton hybrids developed are in long fibre range, while none are in medium, medium long or short fibre length types
- Consistent improvement in fibre quality parameters for industry requirement
- Concept of community refugia suggested to tackle problem of insect resistance
- New novel toxin proteins for resources other than *Bacillus thuringiensis* need to be exploed
- Molecular markers are required to be used profusely for speeding up breeding work
- Each private seed company should be restrict to release 2-3 of *Bt* cotton hybrids
- Improving the level of resistance to biotic and abiotic stresses
- Enhanced water use efficiency, nutrient use efficiency and profits by multitier cropping.
- Need for good quality water for pre sowing irrigation for required plant stand.
- Avoid excessive use of nitrogenous fertilizers *i.e.* urea
- Use of yellow and sticky traps.
- Use diferithiuron, Buprofezin, Pyriproxyfen, spiromesifen for whitefly management.
- Promote long linted spinnable varieties amenable to surgical purpose.
- Promote cultivation of *G. arboreum* in high density plant system (HDPS).
- Clean cultivation leads to fields whitefly free.

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- Dr.(Mrs) Pravasini Behera
- Dr.(Mrs.) Subhrasini Lenka
- Dr.(Mrs.) Mitali Mandal
- Dr.(Mrs.) Lilimony Tripathy

Meeting hall arrangements. Arrangement of Gate, Dais ,Fixing of banner & opening of Souvenir Commitee

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- Dr. Manas Nath

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Sitting Arrangement of Dignitaries and Invitees (Inaugurals & Plenary in hall Dr. M. S. Swaminathan Hall) Committee

- Dr.. J Padhi, Chairman
- Dr..D..Lenka
- (Mrs.)Sarbani Das

Arrangement of PA system

- Er. K. C. Nayak

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2.	Sandeep Bedwal
3.	Deepak Kochar
4.	Naresh Kumar Yadav
5.	Anil Kumar
6.	Ashok Kumar
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8.	Kusum Rana
9.	S. S. Siwach
10.	R. S. Sangwan
11.	Samunder Singh
12.	Siwani

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13.	K. B. Sankat
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15.	Sanjay L. Pawar
16.	Tushar Patel
17.	D. H. Patel
18.	G. R. Dhanderi
19.	B. K. Raj Kumar
20.	H. R. Ramani
21.	K. V. Vadodariya
22.	Rajesh Patel

S. No.	OUAT Bhawanipatna
23.	N. Ranasingh
24.	U. K. Behera
25.	Bishwajit Sinha
26.	Chandana Behere
27.	Srujani Behere
28.	Balabhadra Prasad Gantayat
29.	S. K. Nayak
30.	B. S. Nayak

S. No.	CICR/TNAU, Coimbatore
31.	A. Manivannan
32.	K. Sankaryanayana
33.	R. Vivedha
34.	S. R. Kirthika
35.	S. Thiruvarassan
36.	P. Latha
37.	L. Mahalingam
38.	S. Manickam
39.	A. Manikandan
40.	P. Nalayini
41.	S. Usha Rani
42.	A. H. Prakash
43.	N. Manikandi Bhoopathi
44.	N. Premlatha

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50.	I. S. Katageri, UAS Dharwad
51.	B. S. Janagoudar, UAS Dharwad
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70.	Bishwa Prasad Das
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73.	R. K. Patnaik

S. No.	VNMKV Parbhani
74.	D. B. Deosarkar
75.	P. R. Zanwar

S. No.	RARS, Guntur
76.	Lal Ahamad M.
77.	B. B. Nayak
78.	A.B.M. Sirisha

S. No.	Seed/Pesticide
79.	Veeresh Verma Reddy, Palamore Seeds, Jalgoan
80.	Sushisl Gethar, Agrovet, Mumbai
81.	Dr. H. V. S. Chauhan, Indofil Industries, Mumbai
82.	Vikrant Mohapatra, Indofil Industries, Mumbai
83.	Krishna Patel, Dhanuka Agritech, Gurugram
84.	Baljinder Singh Nandra, Seedworks, Hyderabad
85.	Jandeep Mali, Nuziveedu Seeds, Securanbad
86.	Mohantish B. Satihal, Nuziveedu Seeds, Hyderabad
87.	Ajit Mokele, Ajeet Seeds, Jalgoan
88.	G. B. Ghokhande, Ajeet Seeds, Jalgoan

S. No.	M.P.K.V. Rahuri/Jalgoan
89.	Sanjiv S. Patil
90.	B. D. Jade
91.	R. S. Wagh
92.	R. K. Kolage
93.	N. K. Bhute
94.	R. S. Wagh

S. No.	Dr. P.D.K.V. Akola
95.	Kushal N. Jawanjal
96.	S. B. Deshmukh
97.	N. S. Parde

S. No.	NBRI, Lucknow
98.	S. N. Jena
99.	Gopal Ji Tewari
100.	Babita Joshi

S. No.	UAS, Raichur
101.	J. M. Negagundi
102.	Sushila Nadagoudi
103.	S. G. Hanichal, UAS, Raichur

S. No.	Miscllaneous Scientists
104.	Bharat D. Patel, AAU Anand
105.	N. Prthvi Raj, UAS, Banglore
106.	V. G. Arude, CICROT, Mumbai
107.	R. Veeraputhrian, Srivilliputter
108.	K. Thiyagu, Srivilliputter
109.	T. Ramesh, Warangel
110.	J. A. Patel, Talod
111.	Dr. Krishna Murthy, ARS, Hagori
112.	S. K. Parsai, COA, Khandwa
113.	P. P. Shastry, COA, Khandwa
114.	Mrs. A. Sarda Devi, ANGRAU, Hyderabad

List of Lead, Invited and Other Speakers

S.N.	Name	Address
1.	I.S. Katageri	Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad
2.	S. Manickam	ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore
3.	Ramesh Thatikunta	Agricultural college, Warangal
4.	P.Nalayini	Central Institute for Cotton Research, Regional Station, Coimbatore
5.	Dilip Monga	Head, Central Institute for Cotton Research, Regional Station, Sirsa
6.	A. Sarada Devi	Emeritus Professor, ICAR, ANGRAI, Hyderabad
7.	Samunder Singh	Department of Agronomy, CCS Haryana Agricultural Uniersity, Hisar
8.	Shreekant S. Patil	University of Agricultural Sciences, Dharwad
9.	N. Manikanda Boopathi	Department of Plant Biotechnology, CPMB&B, Tamil Nadu Agricultural University, Coimbatore
10.	Vinita Gotmare	ICAR-Central Institute for Cotton Research, Nagpur
11.	R. S. Sangwan	Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar
12.	K. Sankaranarayanan	Central Institute for Cotton Research, Regional Station, Coimbatore
13.	D. D. Patel	Navsari Agricultural University, Bharuch
14.	Rishi Kumar	ICAR-Central Institute for Cotton Research, Regional Station, Sirsa
15.	S. Usha Rani	ICAR- CICR, Regional Station, Coimbatore
16.	V. G. Arude	ICAR-Central Institute for Research on Cotton Technology, Mumbai
17.	B. K. Raj kumar	Navsari Agricultural University, Main Cotton Research Station, Surat
18.	D. H. Patel	Navsari Agricultural University, Main Cotton Research Station, Surat
19.	S. S. Patil	Mahatma Phule Krishi Vidyapith, Oilseeds Research Station, Jalgaon
20.	L. Mahalingam	Department of Cotton, Centre for Plant Breeding and Genetics, TNAU, Coimbatore
21.	A.Manivannan	ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore
22.	Kusum Rana	Directorate of Extension Education, CCS Haryana Agricultural University, Hisar
23.	S. B Deshmukh	Dr. Panjabrao Deshmukh Krishi Vidyapeeeth, Akola and Maharashtra State Seed Corporation Ltd., Akola -
24.	Dharminder Pathak	Department of Plant Breeding and Genetics, Punjab Agricultural

		University, Ludhiana
25.	Kulvir Singh	Punjab Agricultural University, Regional Station Faridkot
26.	B. D. Jade	Jain Irrigation Systems Ltd. MS (India)
27.	S. L. Pawar	Navsari Agricultural University, Main Cotton Research Station, Surat
28.	R. S. Wagh	Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri
29.	K. B. Sankat	Navsari Agricultural University, Main Cotton Research Station, Surat
30.	R. Veeraputhiran	Tamil Nadu Agricultural University, Cotton Research Station, Srivilliputtur
31.	J. A. Patel	Cotton Research Station, S. D. Agricultura University, Talod, Gujarat
32.	H. R. Ramani	Navsari Agriculture University, Main Cotton Research Station, Surat
33.	B. S. Nayak	Regional Research and Technology Transfer Station (RRTT) OUAT, Bhawanipatna
34.	B. D. Patel	AICRP-Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand
35.	Shruti Mohapatra	Department of Agricultural Economics Odisha University of Agriculture and Technology, Bhubaneswar
36.	Vivek Singh	Directorate of Extension Education, CCS Haryana Agricultural University, Hisar
37.	Amarpreet-Singh	ICAR Central Institute for Cotton Research, Regional Station, Sirsa
38.	S.G. Hanchinal	University of Agricultural Sciences, Raichur
39.	K.N. Jawanjal	Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
40.	P.R. Zanwar	Deapartment of Agricultural Entomology, V. N. Marathwada Krishi Vidyapeeth, Parbhani
41.	Pavitra, N. Sushila	Department of Agrciultural Entomology, Agriculture, University of Agricultural Sciences, Raichur
42.	S.K. Sain	ICAR-Central Institute for Cotton Research, Regional Station, Sirsa
43.	N. Mandi	All India Coordinated Research Project on Cotton, (RRTTS) OUAT, Bhawanipatna, Kalahandi, Odisha
44.	N. Pruthvi Raj	Department of Agronomy, University of Agricultural Sciences, Dharwad
45.	Sandeep Bedwal	Department of Soil Science, Central Soil Salinity Research Institute, Karnal
46.	Deepak Kochar	Department of Soil Science, CCS Haryana Agricultural University, Hisar
46.	B.B Nayak	ANGRAU, Regional Agricultural Research Station, Guntur
47.	A. B. M. Sirisha	Department of Genetics and Plant Breeding, Agricultural College, Bapatla
48.	Harjeet Singh Brar	Punjab Agricultural University, Regional Research Station, Bathinda

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