J. Cotton Res. Dev. **38**(1), 7-18 (January, 2024) **ISSN No. 0972-8619**

Emerging Challenges in cotton Cultivation and Strategies for Improving Productivity in North zone of India

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Abstract : Since Independence, maximum cotton productivity in India was recorded in the year 2013-2014 and except one or two years, the productivity of cotton has decreased considerably over the years. The cotton crop faces numerous problems starting from field establishment to maturity *viz.* seedling burning, heat stress, drought and salinity stresses, trash during picking, and post harvest management problems like pest and disease incidence at different crop stages including nematodes and parawilt/sudden wilt problems etc. Besides them, lack of mechanization, lack of efficient irrigation facilities, nutrient deficiency, non-judicious use of pesticides and fertilizers, late sowing, widening of sowing window, same cropping pattern, improper management of cotton stalks, etc. are major problems related to cotton cultivation in north India. These issues singly and most frequently in combination resulted into lowering the cotton productivity in north cotton growing zone of India. Emerging challenges related to cotton cultivation are discussed in detail and ways to enhance the cotton productivity in north zone are addressed.

Keywords: Cotton, genetic variability, north zone, pink bollworm, productivity, sudden wilt

India is the largest producer of cotton in the world with 5900 ('000 Metric Tonnes) production in 2021-2022 which is about 23 per cent of the total world production *i.e.* 25733 ('000 Metric Tonnes). In terms of area, it is also at first position in the world *i.e.* 12650 ('000 Hectares) which comprises about 49 per cent of total world area of 33188 ('000 Hectares). In 2020-2021, India's cotton production has declined by 2.31 per cent to 352.48 lakh bales as compared to 360.65 lakh bales in 2019-2020 as per the estimates of Directorate of Economics and Statistics; while it again reduce by 12.33 per cent in 2021-22 (312.03 lakh bales) compared to 2020-2021 (DES, Ministry of Agriculture and Farmers' Welfare, 2021-2022). India still manages to maintain the position of top producer in the world due to high area under cotton cultivation. Central zone remained at top in production parameter due to the largest contribution of Gujarat and Maharashtra which secured first and second position among all Indian states with 90 lakh and 84 lakh bales, respectively. But in terms of growth, only North zone has given positive results with slight increase of 0.7 per cent over previous season to 65.50 lakh bales. Among Northern states, Rajasthan topped the list with 10.34 per cent growth and contributed around 49 per cent in the zone with 32 lakh bales of cotton. Haryana remained at second in the zone but its production reduced by 15.1 per cent in 2020-2021 to 22.50 lakh bales. Punjab has the least production among all North Indian states *i.e.* 11 lakh bales but it has shown a good jump in growth of 11 lakh bales over previous season. India has a good record in cotton production but productivity has always been a major challenge for India. In terms of productivity, India ranks 42nd with 466 kg/ha which is lesser than world average of 775 kg/ha. China has the highest productivity out of total 56 cotton growing countries with 1844 kg/ha yields of cotton lint (Data Portal, ICAC, 2021-2022). Since the year 1947, maximum cotton productivity in India was

recorded in the year 2013-2014 *i.e.* 566 kg/ha and except one or two, the productivity of cotton has decreased considerably over the years since then. Within the North zone, Rajasthan has achieved the highest productivity *i.e.* 673.27 kg/ha in 2020-2021 with an increase of 3.79 per cent over previous year. Whereas, the neighbouring state Haryana has shown steep decline of 14.9 per cent in productivity over previous season. Punjab has also come out with the productivity of 373.25 kg/ha of cotton (AICRP on Cotton Annual report 2020-2021). *Bt* cotton is the only GM crop approved by GEAC for commercial cultivation in India and it occupies more than 90 per cent of total area under cotton cultivation (Verma *et al.*, 2021). Besides productivity, there are some other issues related to cotton cultivation in North India. During its life cycle, the cotton crop faces numerous problems including burning of seedlings, infestation of insect pests, diseases, heat, drought, cold and salinity stresses, trash during picking, and post harvest management problems. Besides them, lack of mechanization, lack of efficient irrigation facilities, nutrient deficiency, non-judicious use of pesticides and fertilizers, late sowing, same cropping pattern, improper management of crop debris, etc. are some other problems related to cotton cultivation.

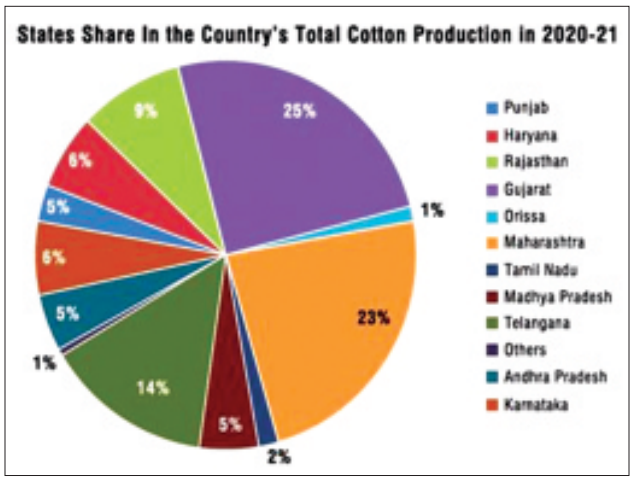

Fig. 1 Cotton Production Shares in Country 2020-21 (Source: https://www.textileexcellence.com/featured/indias-cotton-production-declines-by1-37-in-2020-21-season)

CHALLENGES FOR HIGHER PRODUCTIVITY

1. Narrow genetic variability

There is need to quantify the genetic divergence among available BG II genetic materials through breeding approaches (Govindaraj *et al.*, 2015) as the previous researchers reported the genetic basis of cultivated BG II cotton hybrids is narrow in nature which is becoming a hindrance in sustaining cotton productivity (Waghmare, 2022; Abdukarimov *et al.*, 2003; McCarty *et al.*, 2005). Successful breeding program depends on the inclusive knowledge and understanding of the genetic diversity within and among the elite genetic materials of the existing germplasm. An inclusive and comprehensive knowledge of the genetic diversity both within and among the elite germplasm materials is essential for a successful breeding program. Despite the cotton cultivars being selected for stress resistance, these have been developed more slowly as compared to yield parameters. So, the issue is still need to be addressed to develop resistant hybrids and varieties. There is close relationship between deficiency and resistance factors that restricts the process of cultivating new material. Even though several research works have been aided with use of molecular markers but these are mainly focused on crop yield and fiber quality enhancement (Darmanov *et al.*, 2022). Also the lack of anti inverse and stress response targeted factors with real value delayed the utilization of germplasm materials for creating resistance and variability (Saud and Wang, 2022)

2. Pest incidence

Cotton crop has always remained in stress by sudden outbreaks of pests at different times. Earlier, it was whitefly epidemic in 2015 which devastated the cotton crop in North India in about 1.47 million ha area [Haryana-5.76, Punjab-4.50 and Rajasthan 4.47 lakh ha] (Kumar *et al.*, 2020; AICRP on Cotton Annual Report 2015-2016) and the reduced the yield

Table 1: Insect-pests status of cotton from the year 1970 to 2022.

Name of insect	Upto 1970	1971-80	1981-90	1991-2000	2001-2010	2011-15	2016-20	2021-22
Whitefly	Minor	Minor	Minor	Major	Major	Major	Major	Major
Thrips	Minor	Minor	Minor	Minor	Minor	Major	Major	Major
Leafhopper	Major	Major	Major	Major	Major	Major	Major	Major
Aphid	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor
Mealy bug	-	-	-	-	Major (New)	-	-	-
Dusky cotton bug	-	-	-	-	New	-	Minor	-
Mirid bug	-	-	-	-	New	-	-	-
Spotted bollworm	-	Major	Major	Major	Minor	Minor	Minor	Minor
Tobacco caterpillar	-	-	New	Minor	Major (Sporadic)	Minor	Minor	Minor
American bollworm	-	New	Minor	Major	Minor (after 2003)	Minor	Minor	Minor
Pink bollworm	Major	Major	Major	Minor	Minor	Minor	Major	Major

Source: Dhawan *et al.*, 2008; Kumar *et al.*, 2019 & Kumar *et al.*, 2022.

upto 35 per cent than average productivity of Punjab and now pink boll worm which has suddenly evolved as a pest of major concern in Northern India since its outbreak in 2021 due to field evolved resistance to Cry toxins. PBW was encountered in North India in 2018 in BG II hybrids at Jind in Haryana and Bathinda in Punjab in cotton fields adjoining ginning cum oil extraction mills. It has been transported from Central and South India along with cotton seed brought by ginning cum oil extraction mills. Farmers in highly infested areas had faced 75-100 per cent crop loss during outbreak (Nagrare *et al.*, 2023). The threat still prevails as PBW infestation has been reported recently at the early stage of cotton crop cycle in Hisar and Sirsa districts of Haryana and Bathinda and Faridkot districts of Punjab which demands proper survey and surveillance at regular intervals to counter the pest (Nagrare *et al.*, 2023). During recent past years thrips incidence also been noticed beyond its functional window in North zone (Cotton Statistics and News, 2023).

3. Poor plant stand

During the period of April and May, which is a recommended window for sowing of irrigated cotton in North India, low emergence in cotton is experienced as a result of heat waves during which temperature reaches above 40°C in North India; if emergence happens, the seedlings being sensitive couldn't be able to survive the heat stress and ultimately died. Sometimes formation of soil crust due to untimely rains within 2-3 days of sowing followed by early drying of fields also resulted into poor field emergence especially in North cotton growing zone. The farmers 'field survey consisting three states (Punjab, Haryana and Rajasthan) in North zone showed reduction in plant population ranging from 13 to 45 per cent during 2022 (Unpublished).

4. Lack of irrigation water

Due to uneven rainfall pattern, the farmers of Punjab, Haryana and some parts of Rajasthan mainly rely upon the availability of canal water and ground water for irrigation but in last few years there has seen a rapid depletion in

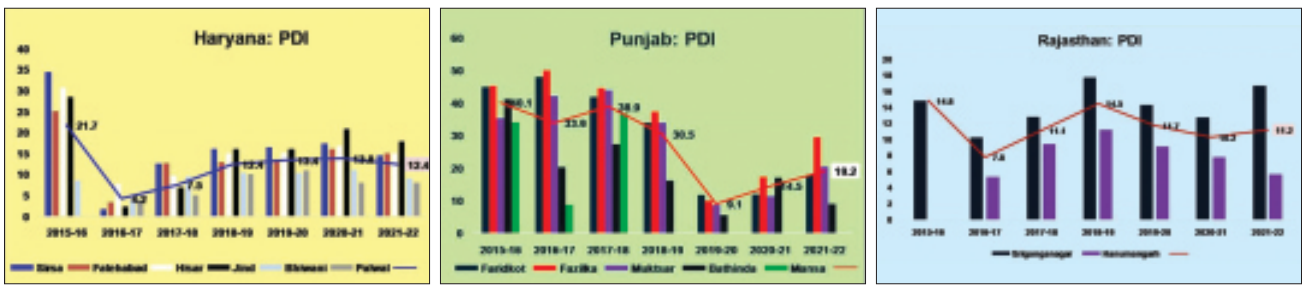

Fig. 2. CLCuD progress in three states (Punjab, Haryana and Rajasthan) of North Zone from the year 2015-16 to 2021-22.

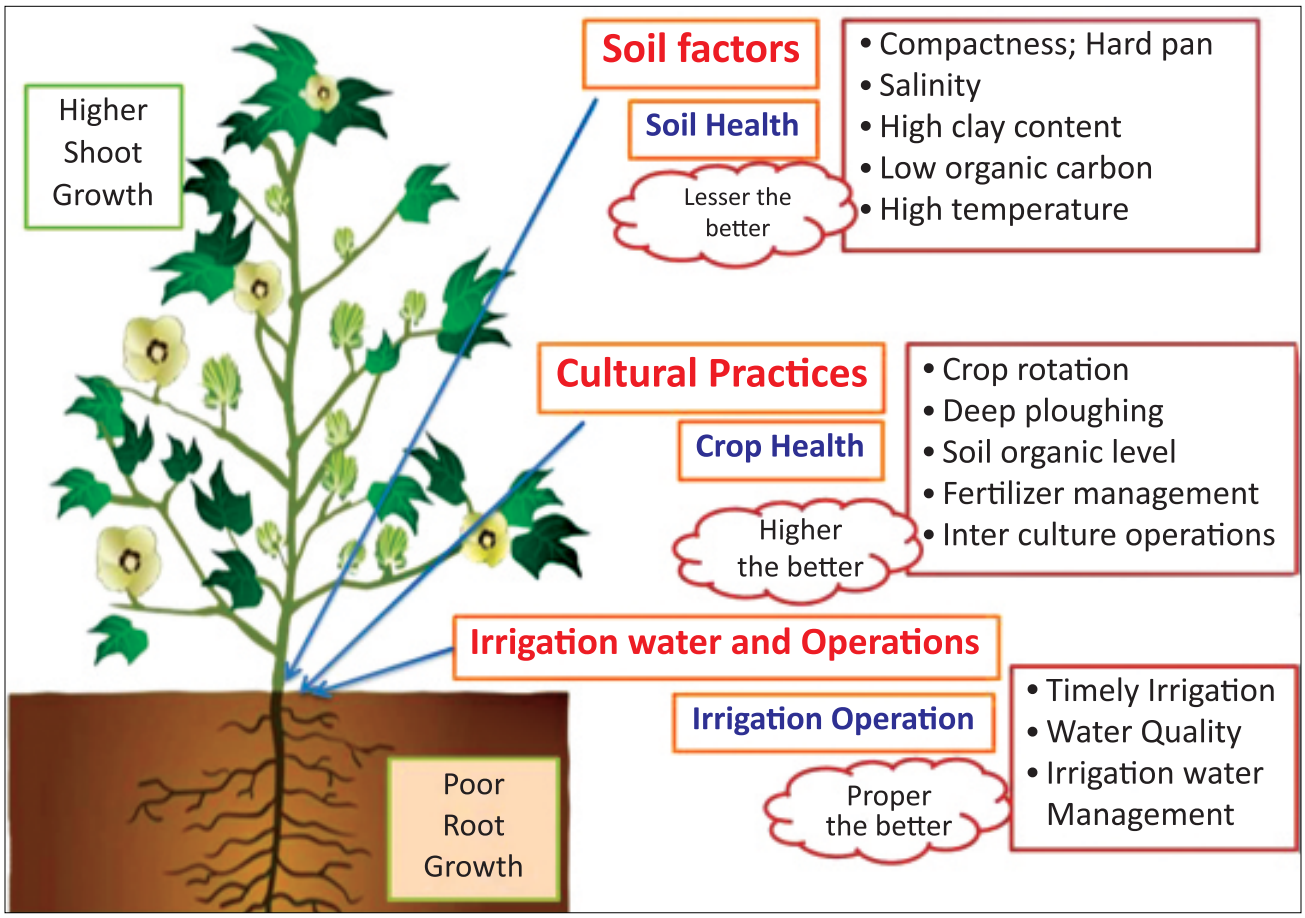

Fig. 3. Salient factors contributing to sudden wilting in cotton plants during crop growth period

groundwater due to over exploitation. The groundwater level in Punjab has drafted drastically from 8 meter in 1999 to 15 meter in 2014 due to total annual groundwater draft by 14.56 BCM which is higher than the sustainable limit (Srivastava *et al.*, 2015; Srivastava *et al.*, 2017). The total climatic water requirement of cotton is about 700-1000 mm, which depends on time of sowing and varies from genotype to genotype, region to region, soil to soil and scientific management to farmers' management. In the recent time the unavailability of canal water at the time of sowing leads to wider sowing window and which invites the major insect pest of cotton, ultimately leading to lower yield.

5. Cotton Leaf Curl Disease (CLCuD)

Cotton leaf curl disease (CLCuD) is a major threat to cotton production and productivity in North India. The CLCuD incidence was estimated to 20.7 per cent in the year 2018 and 26.3 per cent in 2019 and it was observed lower than in the previous years (Duhan *et al.*, 2020, Verma *et al.*, 2021)). CLCuD infected plants exhibit mainly vein thickening, curling of leaves, floral inhibition and stunted plant growth (Briddon *et al.*, 2001). CLCuD is caused by begomovirus (family: Geminiviridae) having single stranded (ss), circular DNA genomes and associated with satellite molecules *viz.*, beta satellite and alpha satellite and it is transmitted through its vector, whitefly (*Bemicia tabaci*). It is widely spread among cotton growing zones of North India (Gupta and Kumar, 2017; Verma *et al.*, 2021). During 2015 another CLCuD epidemic caused by CLCu MuV was experienced with whitefly outbreak (Datta *et al.*, 2017). The disease has also been recorded in Pakistan and China in the last decade, and it poses a risk to all nations that cultivate cotton and has its

Fig. 4. Poor root development due to hard pan formation

prevailing vector, whitefly (*Bemisia tabaci*) and its secondary hosts (Cai *et al.*, 2010). There is a risk that the disease will spread rapidly to unaffected areas if the resistance lines are not being developed (Sattar *et al.*, 2013; Rahman *et al.*, 2017; Schoonmaker *et al.*, 2023). The farmers' field survey consisting of three states (Punjab, Haryana and Rajasthan) in North zone showed CLCuD appearance in cotton fields' ranging with PDI from 4.2 to 40.1 during the period 2015 to 2022. The threat still prevails as CLCuD has been reported in 2022 at the early

stage of cotton crop cycle in districts of Punjab, Haryana and Rajasthan which demands proper survey and surveillance at regular intervals to counter the disease.

6. Nematode problem

In Northern India, root knot nematode (*Meloidogynae incognita*) is an important parasite of the cotton crop with 50-70 per cent frequency of occurrence. The annual cotton yield loss due to *M. incognita* in cotton is estimated to be 20.5 per cent in India (Kumar *et al.*, 2020). Beside it, plant parasitic nematodes such as *Rotylenchulus reniformis*, *Hoplolaimus* sp., *Helicotylenchus* sp. and *Tylenchorhynchus* sp. were also found associated with cotton crop in different parts of India.

7. Parawilt/ Sudden wilt

Parawilt is an important disorder that has been identified in *Bt* cotton hybrids. It involves sudden drooping of leaves when irrigation/rainfall applied after a long dry spell (Sarlach *et al.*, 2008; Sarlach and Kaur, 2013). It was first reported in 1978 from Adilabad district of Andhra Pradesh on rainfed cotton, but now it is prevalent to varying regimes in many other cotton growing regions. Problem of wilt in cotton is increasing in India since last one decade. In 2018-2019, 29.7 per cent of cotton fields showed typical wilting symptoms form September onwards in Rajasthan, Haryana and Punjab states of North India (Singh *et al.*, 2022). The problem occurred due to no deep ploughing, similar cropping pattern (cotton wheat cotton) for more than 5 years and early irrigation (30 DAS) (Sain *et al.*, 2021).

8. Hard pan formation

In the recent times farmers are using rotavator extensively for the intercultural operation in cotton. The machine usually turns the soil only in surface layers but the tynes does not enter deep in soil system. Repetitive use of this machine sometimes leads to development of the hard pans under the surface soil. Other than this degradation of soil health especially soil organic matter also leads to formation of hard pan. The reduction in field emergence and corresponding yield losses were reported to be varied from 29.4 to 31.2 per cent due to variable factors (AICRP on Cotton Annual Report 2022-2023).

9. Poor soil health

Since green revolution, chemical fertilizers, herbicides and pesticides have been used in agriculture in North India. Cotton is one of those crops in which high amount of pesticides are being applied (Thind, 2015). Due to its non judicious use for such a long period, the soils of North India have become toxic with high residue levels (Mishra *el al.*, 2021). Moreover, the problem of sodicity and salinity (Choudhary *et al.*, 2011) also prevails in some parts of Haryana, Punjab and Rajasthan which hampers the cotton crop to reach upto its maximum potential.

10. Non judicious use of insecticides

Unapproved pesticides at non recommended doses when used for a particular pest by the farmers leads to the development of resistance in pest, hormoligosis and pest resurgence. These conditions further lead to severe outbreaks due to non effectiveness of pesticides used. In addition, it also deteriorates the soil health by increasing the residue level in soil and make the soil toxic and less productive. Most recently the practice of tank mixtures of insecticides and growth regulator or nutrients often shows plant toxicity due to complex chemistries and leads to lowering of the actual yield potential of the hybrid. (Kumar *et al.*, 2022). Moreover, mixed use of two or more insecticides at sub lethal concentrations has also resulted in soil deterioration and crop damage, in addition contributed to development of resistance in pest and pest resurgence (Dhaliwal *et al.*, 2010).

11. Lack of mechanization

Due to small Land holding the wide spread practice of mechanized farming is still not much explored in North India. Cotton is a labour intensive crop and the timely picking requires huge amount of manual labour still now. The unavailability of skilled labour for different operations specially picking leads to wastage of seed cotton in the field leading to poor harvest and ultimately lower productivity. (Konduru *et al.*, 2013).

12. Nutrient deficiency (especially micronutrients)

Micronutrients also play a significant role in crop growth. These are generally not applied and plant has to depend on soil for meeting its demand. Most commonly recorded micronutrients in cotton are zinc and boron which play a major role in plant growth and development. Deficiency of micronutrients leads to development of leaf reddening and necrosis and ultimately lower yield (Raju, 2017, Miyatra *et al.*,2013; Gade *et al.*, 2013).

OPPORTUNITIES TOWARDS ENHANCING PRODUCTIVITY:

1. Integrated pest management (with special emphasis on management of PBW)

Window based application of insecticides and proper surveillance of the fields are the need of the hour for proper management of the insect pests (Mohan *et al.*, 2014). The spraying schedule must be followed as per the Economic Threshold Level (ETL). The installation of pheromone traps 2/acre may be a solution for proper surveillance of pink bollworm. The removal/management of PBW carryover present in the cotton stalks lying in the farmers' field and in the cotton seed (*binola*) at ginning cum oil extraction mills, use of Specialized Pheromone and Lure Application Technology (SPLAT) may be the possible way out for fruitful management of PBW. A recent survey during the last year covering the North cotton growing region in ginning cum oil extraction mills showed a significant presence of PBW pupae and double seeds in the samples collected from the oil extraction mills demand a proper surveillance and management of PBW in this present season (Cotton Innovate, 2022). Off season management of cotton stalk, covering left of seed cotton and cotton seed in ginning cum oil extraction mills is need of the hour to manage the pink bollworm incidence. Research has also been started to incorporate the resistance for Cotton Leaf Curl Disease (CLCuD) from wild germplasm sources to the cultivated varieties and hybrids through identification of nature of resistance gene action and mapping of the resistance gene (Verma *et al.*, 2021, Sodha *et al.*, 2022).

2. Timely sowing of the crop

Narrow sowing window between April 15 and May 15 is to be practiced. Planting during this time of year may results a higher harvest while protecting against disease causing insects and pests. It is best to sow in the morning and evening.

3. Action by state Govt./State Dept. of Agriculture

If necessary to boost productivity, the relevant department or officials should conduct workshops, awareness campaigns, and programmes on a trial basis. Front line demonstration approach should be adopted. Good quality seeds of improved varieties along with other required materials can be distributed to the farmers to enhance the productivity. Necessary action should be taken regarding the timely availability of canal water to the farmers for timely sowing and better management of the crop.

4. Deep ploughing

To break the hard soil pan, cross sub soiling at 1.0 m spacing or operate mould board plough for deep ploughing before preparing the

field. This will help in breaking the hard pan, increasing water infiltration and better root development of cotton plants. Properly developed root system will effectively withstand the sudden wilt problem also (Sain *et al.*, 2021).

5. Soil health management

Soil amendments and naturally mined permitted (or regulated) producta can be employed to supplement native fertility (Sharma *et al.*, 2011; Sonune *et al.*, 2012). For maintaining the soil health crop rotation with legumes, cover cropping, green manuring, compost (vermi compost, FYM), bio mulches, biofertilizers may be employed. However, the largest factor responsible for soil health management is clearly the conservation tillage practices along with integrated nutrient management (Sonune *et al.*, 2021).

6. Refinement of cultivation practices

Spraying of 2 per cent potassium nitrate (13:0:45) at weekly intervals starting at flower initiation may be done to get higher yields. Management of leaf reddening in *Bt* cotton should be addressed by 2 spraying of 1 per cent magnesium sulphate (2.5 kg magnesium sulphate in 250 litres of water)/hectare) at 15 days interval during full bloom and boll development stages four times may be performed. The refinement in agronomic practices like canopy management, use of defoliants for making the genotypes suitable for machine picking under High Density Planting System (HDPS) system and district wise cotton productivity maps can also be taken into consideration for increasing cotton productivity (AICRP on Cotton Annual Report 2021-2022).

7. Area based approach

There is a need for selection of suitable variety of hybrid based on stability of the genotype at the particular area. The choice of a hybrid/variety may be done based of the previous insect pest incidence pattern and tolerance of a genotype towards it, adaptability of the genotype to the particular area, fertility response of that particular genotype and the soil fertility status of the region etc. Research on revisiting of optimum plant population, doses of fertilizers and other nutrients (Gade *et al.*, 2013; Xiao and Yin, 2019), genotype wise spacing should also be initiated to exploit the potential yield of the hybrid/variety and ultimately enhance the productivity.

Nutrient deficiency symptom in cotton

8. Micro irrigation and fertigation

Cotton requires 4-6 irrigations depending upon the seasonal rainfall. In North zone 95 per cent area under irrigation by bore well and canal water (Ramaswami,2021; ICAC plenary meeting). It was observed that the first irrigation should be given 4 to 6 weeks after sowing and the subsequent ones at an interval of two or three weeks (Sain *et al.*, 2021). However, on light soils or in crop sown on ridges, the first irrigation may be advanced, if necessary. Cotton during its early growth is very sensitive to water stagnation. Therefore, drain out the stagnant water if such a

situation arises. To hasten boll opening, give the last irrigation by the end of September. In water scarce areas, micro irrigation or fertigation can be adopted which not only save water and fertilizer but increase their usage efficiency (Jayakumar *et al.*, 2015)

9. Mechanized and precision farming

In modern agriculture, there is a wide scope of mechanization starting from ploughing till post harvest operations (Ramanjaneyulu *et al.*, 2021). Each and every operation can be performed more precisely by inducting them into the system. For precision farming, technology is the key component for enhancing the productivity. In cotton, use of precision planters for sowing, drones for monitoring, spraying and imaging, cotton stalk chopper for mixing of cotton stalk in soil should be encouraged (Ramanjaneyulu *et al.*, 2021).

CONCLUSION

Selection of suitable hybrid/variety, proper management of the crop and better surveillance of the insect and disease during the total crop growth period. The productivity can be enhanced by proper physiological and nutrient management, timely release of canal water for timely sowing, use of micro irrigation and fertigation, development of commercially successful *Bt* cotton varieties, breeding efforts to incorporate biotic and abiotic tolerance genes, use of nano particles and nano fertilizer, awareness and recommendation for ginning and oil extraction mill owners about the carryover of PBW in the cotton stalks which ultimaltely lead to higher productivity. Development of mobile app for farmers, cross state learning can also be initiated for proper dissemination of the technology developed by the various stakeholders. Use of beneficial organisms/insects, rain water harvesting strategies, seed production as an option for rural business, availability of quality seed to the farmers, holistic approach for management of emerging issues in cotton production, transgenic approach for management of whitefly in cotton, timely advisory for farmers and strategies for upcoming years to make schemes on cotton and diversification of species and strategic research should also be encouraged to increase the productivity of cotton.

Conflict of interests

Authors declare no conflict of interests.

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Received for publication : December 6, 2023
Accepted for publication : December 22, 2023