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Review Article

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Response of Cotton to Varied Levels of Agronomic Management Under High Density Planting System (HDPS) – A Review

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Abstract

Cotton, a crop of choice, occupies the second premier position next to food crops in providing clothing. Though 53 species of Gossypium are available, only four species are cultivable and among the four, the major cultivable area falls under G. hirsutum. Though varieties with medium, superior medium, long and extra-long staple cotton were released earlier, with the advent of machineries, ginning facilities, mills were literally requiring cotton fiber of any length. With the advent of Bt technology and the release of hybrids during 2002, cotton productivity had gained a momentum. However, considering the duration, cost involved in manual harvesting etc., farmers were looking for alternate option especially under rainfed conditions and High-Density Planting System (HDPS) with compact cotton genotypes is the viable alternative to overcome the stagnant productivity despite following all the suitable agronomic measures like adopting BG II hybrids, maintaining optimum plant population density and following timely plant protection measures. HDPS technology increases the number of bolls per unit area to achieve a high yield, reduces the risk of terminal drought and failure due to pests, gives seed sovereignty to farmers, and is specifically suited for rainfed areas with shallow and medium-deep soils. Under HDPS entries could yield better at 60×10 cm^2 spacing under medium depth soils with a planting density of 1.66 lakh plants ha^{-1}. Cotton planted under HDPS need 25% additional fertilizers over the recommendation for varieties.

Keywords: Cotton, high density planting system, genotypes, planting geometry

1. Introduction

India is the largest producer cum leading consumer of cotton in the World. In India, though the area under cultivation of cotton is higher, the seed cotton yield per unit area is very low compared to many other cotton growing countries in the world.Venugopalan (2019) reported that cotton productivity in India during 2018–19 was lowest despite the fact that almost 90% of the farmers have adopted state of the art BG II hybrids. He further stated that the cost of cultivation of cotton increased from 2233 q^{-1} of seed cotton in 2002–2003 to 4803 q^{-1} in 2015–16 which is mainly due to increased use of inputs like fertilizers and pesticides and labour wages. In a bid to beatthe stagnancy and improve yields in cotton, High density planting system (HDPS) is one of the strategies thatcould maximize the per unit area yield by exploiting more unit area productivity. The optimum level of cotton productivity would, however, depends on the plant type being grown. The present-day hybrids put forth biomass enormously with more horizontalspread in nature with low ratio of bolls to biomass. For having a match between the growth, water requirement, duration, yield per unit area etc. this system of HDPS, an initiative by the Central Institute of Cotton Research (CICR), Nagpur offers a viable alternative for higher yields with low production costs under rainfed condition. The main tenets of this proposition cover tailoring a genotype suiting to high density planting (more than one lakh plants per hectare), its uniformity in boll development, maturation and bursting, its adoptability to the given condition and efficiency in the nutrient utilization etc. In addition, to overcome labour shortage, mechanization is the need of the hour. Mechanical picking warranted short, compact (short sympodes) and determinate plants. To retain their architecture and maximize productivity from these plant types, close planting was a necessity. For this, compact genotypes are ideally suited which offer great scope for reducing not only row width, butalso spacing between the plants in a row.

2. High Density Planting System (HDPS) of Cotton

The concept of High-Density Planting System (HDPS) was initiated by Briggs et al. (1967) by adopting narrow row plantation. It has been reported that narrow row planting increase productivity of cotton (Ali et al., 2010). Earliness is the advantage of narrow row planting (Rossi et al., 2004). Due to narrow planting, though there is reduction in number of bolls per plant, it results inhigher percentage of the total bolls in first sympodial position, while lower in second position (Vories and Glover, 2006). The other advantages of narrow row planting include better light interception, sufficient leaf area and early canopy closure, resulting in weed control (Wright et al., 2011). Currently in India, depending on the local conditions, hybrid cotton is planted at row spacing ranging from 90–120 cm and plant spacing ranging from 30–90 cm resulting in 15000 to 25000 plants ha^{-1}. In HDPS, short duration, semi-compact cotton varieties are planted at populations ranging from 1.1 lakh to 2.45 lakh plants ha^{-1} by planting at a distance of 45–90 cm between rows depending upon the soil type and growing conditions and 10 cm between plants in a row. It aims to establish around 7–8 plants m^{-1} row length. The objective is to limit the boll number to 6–8 bolls $plant^{-1}$, maximize the number of bolls $unit^{-1}$ area and realize high yield in the shortest possible time. If the number of bolls $plant^{-1}$ is few, the fruiting window (or flowering period) is short (4–5 weeks) and the plant matures early, producing fibers with good quality. .Ultra narrow row (UNR) cotton production is considered as a potential strategyfor reducing production costs by shortening the growing season (Rossi et al., 2004). By cultivating the genotypes that would fit for UNR, it provides the scope for increasing per unitarea of plants *vis-a-vis* the productivity. Being shorter and earlier to mature, thesegenotypes under UNR provides scope for double cropping and mechanical harvesting. Since the number of bolls are less with uniformity in maturation and bursting,these compact types require few pickings only. This results in savings of labour costas well as seed cost as it provides farmers an opportunity to reuse the varietal seeds for few sowing seasons. Adoption of HDPS with amicable compact and early maturing cotton varieties offers sustainable production at decreased cost under Indian conditions. However, availability of more determinate cultivars, more efficient options of weed control and insect pest management (including transgenics), growth regulations to modify morpho frame, planting and harvesting equipments etc., has made high density cotton planting system popular in several countries.

3. Availability of Suitable Genotypes

Availability of early maturing, compactsympodial plant types with more fruiting bodies closer to the main stem is a prerequisite for successful HDPS. AICRP on Cotton started a separate trial on the evaluation of compact genotypes for HDPS under rainfed and irrigated situation, to facilitate release of compact genotypes suitable for HDPS. Variety CSH 3075 was the first cotton variety released for HDPS in India. Semi-compact genotypes like PKV 081, Suraj, NH 615, NH 630, ADB 39, LRK 516, F2383, CSH 3075, ADB 39, NDLH 1938 and KC 3 Cotton association of india 16th April, 2019 3 in *G. hirsutum* and Phule Dhanwantary and AKA 7, yaganti in *G. arboreum*, have morphological traits to fit into HDPS at appropriate row spacing. In these genotypes the average yield improvement under HDPS was around 30% over the recommended spacing (60×30 cm^2) and the earliness was around 10 days.

4. Growth Manipulation

The very purpose of compact cottoon genotypes suitable for HDPS would be achievedonly by manipulation of row spacing, plant density and the spatial arrangements of cotton plants for obtaining higher yields. The most commonly tested plant densities range from 5 to 15 plants m^{-2} resulting in a population of 50,000 to150,000 plants ha^{-1}. In UNR system of cotton, plants produce less number of bolls perplant than conventional cotton but retain a higher percentage of the total number of good opened bolls per unit area in the first sympodial position and a lower percentage in the second position (Kumar et al., 2018). The other advantages include better light interception, efficient leaf area development and early canopy closure which shades out theweeds and reduce their competitiveness (Amudha et al., 2011). The early maturity in soils that do notsupport excessive vegetative growth (Deguine et al., 2008) can make this system ideal for shallow tomedium soils under rainfed condition where conventional late maturity hybrid sexperience terminal drought. Cotton growth must be regulated and eventually terminated by chemical means,due to the plants' intrinsic indeterminate growth habit. Plant growth retardants are natural or synthetic organic compounds that control or modify one or more physiological events in plants. These synthetic compounds are widely used in cottonfor reducing plant height. The plant growth retardants affect many physiological functions in plants. The crop growth regulator Mepiquat Chloride (MC) is commonly used in cotton in China and elsewhere to maximize cotton yieldand fiber quality (Shaban et al., 2018; Fatouh et al., 2011). The application of MC increases leaf thickness, reduces leaf area (Sathish et al., 1999), shortens internodes (Fernandez et al., 1991) and decreases plant height (Pangga et al., 1991) and thusresults in a more compact plant architecture (Pushavathi et al., 2017).

5. Plant Density

Theoretically, higher planting density ensures earlier crop canopy cover, higher sunlight interception leading to higher and earlier yields at reduced cost. The obvious advantage of this system is earliness (Latha et al., 2011) since UNR planting system results in lower number of bolls $plant^{-1}$ with higher number of bolls per unit area to achieve the same yield as conventional cotton and the crop does not haveto maintain the late formed bolls till maturity. In general, it was observed thatlower plant densities produced higher values of growth and yield attributes per plant, but yield per unit area was also higher with higher plant densities (Oosterhuis and Egilla, 1996; Zhang et al., 2018; Ramprasad et al., 2019). Fertilizer and pest management are important consideration for increased yieldsunder high density planting system. Changes in planting density modifies themicroclimate and this may alter the incidence of pests and diseases as well (Jagtap and Dey, 2013). Studies taken up using the genotypes AKH 081, Suraj and NH

615 under HDPS revealed that these entries could yield better at 60x10 cm^2 spacing under medium depth soils with a planting density of 1.66 lakh plants ha^{-1} on broad bedfurrow (BBF) with 125% of recommended fertilizers (75:37.5:37.5 NPK+2.5Zn kg ha^{-1}) along with a foliar spray of 1% urea and 1% magnesium sulphate at bolldevelopment stage (Cia et al., 2016).

6. Planting Geometry and Nutrient Management

All of the genotypes did not respond favorably to high density planting. Silva et al. (2012) and Rossi et al. (2007) observed significant interaction between plant density and genotypes. Significantly higher seed cotton yield (1205 kg ha^{-1}) was recorded with the spacing of 60×10 cm^2, probably due a greater number of bolls per unit area (Shukla et al., 2013; Sisodia and Khamparia, 2007). Genotype NH615 was found to be most suitable for HDPS on the basis of its morphological features, earliness, tolerance to sucking pests and boll weight. Arboreum cotton variety Yaganti cultivated under high density planting system (45×15 cm^2) with the application of 150% RDF (30–30 NP kg ha^{-1}) registered higher seed cotton yield of 1670 kg ha^{-1} under rainfed conditions in vertisols of Andhra Pradesh (Basha et al., 2017). Whereas American cotton variety NDLH 1938 cultivated under high density planting system (45×15 cm^2) with 150% RDF (60-30-30 NPK kg ha^{-1}) recorded higher seed cotton yield of 2265 kg ha^{-1} under rainfed conditions on vertisols of Andhra Pradesh (Basha et al., 2017). Similarly, American cotton variety ARBC 64 plantedat 60×10 cm^2 (1,66, 666 plants ha^{-1}) with 125% RDF (112.5-56.25-56.25 NPK kg ha^{-1}) recorded higher productivity of 1015 kg ha^{-1} on vertisols of southern India (Basha et al., 2017). Further, Cotton planted under HDPS need 25% additional fertilizers over the recommendation for varieties. The nutrient uptake efficiency also improved under HDPS. The genotype NDLH 1938 showed best performance and increased seed cotton yieldat 50 kg N ha^{-1} suggesting that it could be the promising cultivar if grown on vertisols under environmental conditions of scarce rainfall zone of Andhra Pradesh (Basha and Aruna, 2016).

7. Soil Moisture Conservation Practices

Soil moisture Conservation practices either by broad bed and furrow (BBF) and ridge and furrows have great potential to benefit cotton production in HDPS under rainfed conditions. These measures increased soil moisture content. The application of bio-mulching or poly mulching on BBF along with drip irrigation on can improve growth, yield and quality of Bt Cotton (Kumar et al., 2022). The growing of Bt. cotton with ridge and furrow between 2 rows or broad bed and furrow with 2 rows at 20 days after sowing and apply plastic mulch (25 micron) or straw mulch @ 5 t ha^{-1} at withdrawn of monsoon in the month of September (38 to 39 Std. week) gave higher productivity and maximum net returns as well as maximum *insitu* moisture conservation and rain water use efficiency under dry farming conditions (Vekaria et al., 2020). The Coir pith application with broad bed furrow is found to be the best practice for enhanced soil moisture availability as compared to other conservation practices for deep clay soils for cotton cultivation (Devaranavadagi and Santhana, 2017)

8. Conclusion

High-Density Planting System (HDPS) with compact cotton genotypes is the viable alternative to overcome the stagnant productivity despite following all the suitable agronomic measures like adopting BG II hybrids, maintaining optimum plant population density, application of 25% additional fertilizers and following timely soil conservation and plant protection measures. It has the potential to end the existing trend of stagnant yields of cotton in India.

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