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Corresponding Author

R. Gouthami

e-mail: gouthamiranapanga28030@gmail.com

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HDPS Cotton - Challenges and Opportunities in India

R. Gouthami[1*], A. V. Ramanjaneyulu[2], U. Nagabhushanam[3], B. Ramprasad[4], J. Kamalakar[5] and M. Yakadri[6]

Abstract

This article provides a concise overview of the high density planting system employed in cotton farming. The adoption of high density planting system in cotton cultivation has led to increased yields vis-a-vis traditional planting methods. While the benefits of embracing high density planting system are evident, there are several challenges that farmers encounter throughout the cultivation process, spanning from sowing to harvesting. However, through the selection of appropriate cotton cultivars, the implementation of tailored cultivation techniques and the incorporation of mechanization in high density planting system of cotton farming, these challenges can be effectively addressed.

1. Introduction

Cotton (*Gossypium hirsutum* L.) holds a prominent position as the primary fiber and cash crop. It is a crop that accompanies humans throughout every stage of life. It is cultivated in over 70 countries. It thrives in both tropical and sub-tropical regions, making it a globally vital crop that plays a substantial role in both agricultural and industrial economies. In India, cotton contributes to approximately 60% of the fiber used in textile production (Venugopalan et al., 2014).

Cotton is predominantly grown under rainfed conditions in India. However, the productivity of cotton is relatively low due to several factors. Firstly, a substantial portion of the cotton fields relies solely on rainfall, which is often unpredictable. Additionally, poor soil fertility, the practice of mono-cropping, the presence of pests and diseases, improper fertilizer usage, low plant density and resistance to adopting improved agricultural techniques further contribute

Author's Address

[1]M.Sc. (Agronomy), College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana (500 030), India
[2]Principal Scientist (Agronomy) & Head, AICRP on Agroforestry, PJTASU Rajendranagar, Hyderabad, Telangana (500 030), India
[3]Principal Scientist (Crop Production), DAAT Centre, Regional Agricultural Research Station, Warangal, PJTASU, Telangana, (506 007), India
[4]Principal Scientist (Entomology), Agricultural Research Station, Adilabad, PJTASU, Telangana (504 001), India
[5]Assisant Professor (Soil Science & Agricultural Chemistry), Agricultural College, PJTASU, Warangal, Telangana (506 007), India
[6]Professor & Head, Department of Agronomy, College of Agriculture, Rajendranagar, PJTASU, Hyderabad, Telangana (500 030), India

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to the overall low cotton yield. Hence, there is a need to increase the production of cotton for improving the financial status of farmers as well as national economy by increasing the area under cotton and plant population ha^{-1}. The High-Density Planting System (HDPS) involves planting crops at closer spacing than the recommended norm, primarily to maximize yield per unit area. The specific spacing requirements can vary depending on the crop genotype. In Brazil, notable achievements in productivity have been realized by developing compact genotypes specially adapted for high-density planting layouts. These genotypes allow for accommodating plant populations ranging from 1.5 to 2.5 lakh plants ha^{-1}, each yielding 8-14 bolls $plant^{-1}$, with individual boll weights averaging 4.0 g. This innovative approach has resulted in significantly higher seed cotton yields, typically ranging between 45 to 55 q ha^{-1} (Kumar et al., 2019).

2. HDPS Initiatives in India

Over the past five decades on a global scale, breeding efforts have been focused on the development of sympodial cotton varieties characterized by fewer bolls $branch^{-1}$, with an emphasis on positioning more bolls in close proximity to the main stem. This dual objective served two purposes: first, to accommodate a higher number of plants within a given row length and second, to enhance the quality of the cotton fibers produced. As a result of these breeding endeavors, the majority of cotton varieties developed over the last thirty years in numerous cotton-growing nations, excluding India, have been tailored to suit narrow row spacing, typically ranging from 38 to 76 cm. These systems have gained widespread acceptance and adoption in several countries. These high density planting systems did not take off in India owing to the following reasons.

➢ Breeding efforts during this period did not specifically focus on the deliberate development of shorter, compact and early-maturing cotton varieties that would bear fruiting structures in close proximity to the main stem. Instead, breeders consistently favored the selection of vigorous plants that could carry a higher number of bolls $plant^{-1}$.

➢ Agronomists did not prioritize High-Density Planting Systems (HDPS) with the specific goal of maximizing productivity per unit area through plant density manipulation. Instead, their research efforts were centered on identifying the ideal geometry and density for a particular cultivar. They also focused on optimizing crop geometry and row spacing to enable various crop management practices such as intercropping, inter-cultivation and soil moisture conservation.

➢ The standardization of plant monitoring techniques for the purpose of using plant growth regulators to modify growth habits and create a suitable morphological framework for integrating existing varieties into high-density planting was never established.

➢ There were concerns that the modified micro-climate resulting from high-density planting might exacerbate weed growth, insect-pest infestations and diseases. However, the evaluation of HDPS systems did not take place with the consideration of the newer, more effective insecticides and post-emergence herbicides available at the time.

Between 2007 and 2012, the Technology Mission on Cotton (TMC) project focused on the identification of *G. hirsutum* genotypes suitable for mechanical picking and the development of an agronomic package, several promising genotypes were assessed. These evaluations were conducted at a spacing of 100 X 10 cm, accommodating 100,000 plants ha^{-1}. However, it was only in 2010 that dedicated efforts to implement high-density planting systems using straight varieties were initiated, led by the Central Institute for Cotton Research (CICR) in Nagpur, through the following projects:

• Development of HDPS for maximizing the productivity of rainfed cotton.

• Development of nutrient management schedule for *G. hirsutum* under HDPS-(TMC).

• Evaluation of compact genotypes for HDPS under rainfed and irrigated situations in different agro-eco regions.

Advantages of HDPS in Cotton

➢ Higher productivity per hectare compared to regular spacing.

➢ Escape from terminal drought and some cotton pests, so well suited for rainfed areas.

➢ Early crop maturity

➢ Synchronous bursting hence, suitable for mechanical harvesting.

➢ High water and nutrient use efficiency.

3. Semi Compact Genotypes for HDPS

Some of the semi compact genotypes recommended by ICAR-CICR for HDPS are CSH 3075, F2383, PKV 081, Suraj, NH 615, BS 279, BS 30, SCS 1206, NDLH

1938, ADB 39, ADB 538, Anjali, Subiksha, DSC 99, ARBC 64, AKH 1317, JK 4, G Cot 16, GISV 272, CO 17. In Telangana NCS 2778 performing well under HDPS (Gouthami et al., 2023).

4. Mechanization in Cotton

The adoption of mechanization in cotton farming can significantly boost yields while also saving approximately 35-40 man-days and 85-90 hours ha^{-1}. This leads to a reduction in production costs by Rs. 8,500-9,000 ha^{-1} and an increase in net income by Rs. 12,000-15,000 ha^{-1}. India offers various opportunities for mechanized cotton cultivation, but, it necessitates the introduction of suitable varieties for mechanical picking, farmer education

Table 1: Challenges faced during the cultivation of cotton under HDPS

Sl. No.	Challenges	Solutions
1.	Type of soils	Cultivating cotton in clay soils results in excessive vegetative growth due to their higher water retention and nutrient content, making them unsuitable for High-Density Planting Systems (HDPS). Conversely, growing cotton in red or light soils reduces vegetative growth, making it more suitable for HDPS. While clay soils also suitable for high-density planting of cotton, but they require careful management to address drainage, soil structure, nutrient availability, weed control and other factors that may impact cotton production. Site-specific considerations and soil testing are essential for determining the feasibility of high-density planting in clay soils and for developing a successful agronomic plan
2.	Selection of suitable cultivars	Long-duration cultivars with dense branching patterns are unsuitable for High-Density Planting Systems (HDPS) due to limited space for each plant and increased vulnerability to terminal drought. Therefore, it is more advisable to opt for compact, early maturing cultivars for HDPS and mechanical harvesting (Kumar et al., 2020). In various regions of India, scientists have assessed different cotton cultivars to determine their suitability for HDPS. Further, research is needed to assess appropriate cultivars that are well-suited for mechanical harvesting
3.	More time required for manual sowing	In HDPS, manual sowing takes more time due to the closer plant spacing. To address this issue and reduce the labor costs, the adoption of pneumatic planters is recommended. The cost of each pneumatic planter is 5 lakh rupees. However, high cost and unavailability at village levels are the main hinderances in the widespread adoption of pneumatic planters in HDPS practices
4.	Higher seed rate	HDPS necessitate a greater seed rate due to their closer plant spacing (75-90×10-30 cm^2), resulting in increased seed costs. However, these higher seed expenses can be offset by the enhanced returns achieved through HDPS cultivation. Optimal plant population is crucial in HDPS. Recommended options include 90 x 15 cm spacing with plant population of 74,074 plants ha^{-1} and 90×30 cm^2 spacing with plant population of 37,037 plants ha^{-1}. The choice depends on specific goals and local conditions
5.	Canopy management	In HDPS of cotton, effective canopy management is crucial. To reduce excessive vegetative growth and retain first formed bolls in HDPS, plant growth regulator (PGR) like Mepiquat Chloride should be sprayed. The Mepiquat chloride application schedule is as follows: ➢The first spray should be administered at 40-45 DAS, when the plant height reaches 50-55 cm, specifically at head square stage @ 1.0 ml lit^{-1} of water ➢ The second spray should be conducted at 15-20 days after the initial application or between 60 to 65 DAS @ 1.0-1.2 ml lit^{-1} of water ➢ A third spray at 80-85 DAS may be necessary in cases of excessive growth, particularly in heavy or highly fertile soils, or due to excess rains or soil moisture @ 1.0-1.2 ml lit^{-1} of water (ICAR- CICR) ➢ However, exact information has to be generated regarding spray at certain plant height and nodal length
6.	Nutrient Management	HDPS needs 25% more fertilizers due to higher plant population compared to conventional planting. It requires soil testing before going to sowing for effective nutrient management. 125% recommended NPK + Zinc sulphate @ 12.5 kg ha^{-1} and borax @ 2.5 kg ha^{-1}. Foliar spray - potassium nitrate @ 7.5 g lit^{-1} of water during boll development phase (Venugopalan, 2019)

Sl. No.	Challenges	Solutions
7.	Soil Moisture stress	The drought stress is more pronounced due to higher plant density in HDPS cotton. Hence, research has to be done to identify cost effective osmo protectants to overcome the drought
8	Weed Management	HDPS ensures quick canopy closure and improves the competitiveness of cotton crop against weeds. Apply Pendimethalin 38.7 % CS @ 3.5 ml lit^{-1} of water as pre-emergence herbicide within 24-48 hours of sowing. One or two hoeings followed by hand weeding at 20 and 40 days after sowing (DAS) keeps the field weed free. If hoeing or hand weeding is not possible due to continuous rains, spray post-emergence herbicide Quizalofop ethyl 5% EC @ 2 ml lit^{-1} of water if the field is infested with grassy weeds, Pyrithiobac sodium 10% EC @ 1.25 ml lit^{-1} of water for broad leaved weeds or Quizalofop ethyl 6% EC+Pyrithiobac sodium 4% EC (combination product) @ 2.5 ml lit^{-1} of water to control both grassy and broad-leaved weeds (Prasad et al., 2023)
9.	Incidence of pest and diseases	The adoption of closer plant spacing creates a microclimate that can promote the emergence of pests (Majorly sucking pests like jassids and thrips) (Prasad et al., 2019) and diseases (Root rot, wilt, leaf spots, BLB and gray mildew). To effectively manage sucking pests in agricultural fields, a combination of neem oil (1 lit $acre^{-1}$) and neem seed kernel powder (1 kg $acre^{-1}$) is recommended. This approach helps control these pests. Additionally, for the management of American bollworm in non-Bt cotton varieties, farmers should follow an action threshold based on the Economic Threshold Level (ETL). When the pest population exceeds this threshold, apply Coragen @ 0.3 ml lit^{-1} of water or Flubendamide (Fame 480 SC) @ 0.2 ml lit^{-1} of water. For the control of pink bollworms, it is essential to monitor the pheromone catch regularly. If the pheromone catch indicates that the pink bollworm population has surpassed the ETL, the recommended course of action is to use Profenophos @ 2 ml or Thiodicarb @1.5 g or Chlorpyriphos @ 2.5 ml along with neem oil @ 5 ml lit^{-1} of water. This integrated approach ensures effective pest management while also considering the specific pest population dynamics in the field (Venugopalan, 2019)
9.	Defoliants	To enhance the efficiency of mechanical cotton harvesting and maintain the quality of cotton fiber, it is essential to minimize the presence of foliar parts in the harvested lint. So, defoliation of leaves at the physiological maturity stage of the plant would facilitate in harvesting the fully opened bolls through mechanical instruments. Defoliants like Ethrel (2000 ppm), Dropp Ultra (0.4 ml lit^{-1} of water) (Thidiazuron) should be sprayed at 50 to 75% of boll opening in case of single picked varieties or mechanical harvesting
10	Availability of labour	Cotton production in India faces significant challenges due to inefficient labor practices, rising labor costs and labor shortages (Ramanjaneyulu et al., 2021). Hence, there exists a substantial opportunity to introduce and expand mechanization in India. This endeavor has the potential to significantly enhance both the productivity and profitability of the cotton sector in the country

on defoliation, the establishment of well-organized custom service centers, and the need for public-private partnerships to develop suitable seeds and machinery for comprehensive cotton mechanization.

5. Opportunities

According to ICAR, red soils constitute approximately 18.5% of India's total land area. These soils are prominently found in several key states, including Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh and Telangana. Given the prevalence of red soils in these regions, there exists a promising opportunity for the adoption of HDPS for cotton cultivation.

- As the textile industry grows and consumer demand for cotton products continues, there is an opportunity for Indian cotton farmers to meet this demand through increased production facilitated by HDPS.
- The government schemes and programmes aimed at promoting innovative and sustainable agricultural practices should include support for HDPS adoption.
- India has limited arable land and HDPS can help make more efficient use of available land resources, allowing for greater cotton production without the need for expansion into new areas.
- For farmers looking to diversify their agricultural practices or income sources, HDPS can provide an

opportunity to explore new techniques and markets within the cotton industry.

➢ HDPS cotton has been shown to produce yields that are up to 30-40% higher than traditional methods. This can lead to increased profits for farmers.

6. Conclusion

HDPS cotton could significantly benefit Indian farmers by enhancing yields, lowering costs and boosting profits. However, challenges like need for more water and nutrients and greater susceptibility to pests and diseases must be tackled. To achieve its full potential, the government and institutions must prioritize affordable access to quality seeds and inputs, investments in R&D for breeding robust varieties and educate farmers through extension programmess. These steps will drive HDPS cotton adoption and success in India.

7. Way Forward

Further research efforts should be directed towards optimizing canopy management strategies tailored to the specific plant stature and the development of cultivars that are well-suited for mechanical harvesting, alongside prioritizing breeding programs aimed at enhancing plant architecture in high-density planting systems

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