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# Influence of plant density on leaf parameters and canopy architecture of Bt Cotton (*Gossypium hirsutum* L.)

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**Abstract**
A field experiment was conducted on the influence of plant density ***vis-à-vis*** architecture on Bt cotton (*Gossypium hirsutum* L.) yield and quality parameters at the College Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during 2021–23. The experiment was laid out in a split plot design with three replications. Among plant densities, leaf area index and light interception rate were observed to be highest in plants planted under 90 × 20 cm spacing (55,555 plants ha$^{-1}$), while the highest specific leaf weight was noticed in 90 × 60 cm spacing (18,518 plants ha$^{-1}$) during both years of study as well as in pooled mean. Non-significant differences were observed for canopy temperature and SPAD readings (chlorophyll content in leaves). Results revealed that physiological parameters, namely leaf area index and light interception rate, were recorded highest under semi-open type canopy architecture. Specific leaf weight was found to be highest in the compact type of plant canopy.

**Keywords:** *Gossypium hirsutum* L, leaf parameters, canopy architecture, leaf area index

## 1. Introduction

Cotton cultivation in India provides direct livelihood to nearly six million farmers, and the textile industry consumes around 60 per cent of the country's total fibre production. India is the largest producer of cotton and occupies the second position in exporting and consumption globally. Cotton in India is grown across three agro-ecological zones, namely Northern, Central and Southern zones. Nearly 70 per cent of the cotton area is cultivated under rainfed conditions, predominantly in the Central and Southern regions.

India occupies an area of 13 million hectares with cotton production of 365 lakh bales (170 kg per bale) and productivity of 459 kg ha$^{-1}$. Among cotton-growing states, Maharashtra ranks first in area (38.06 lakh ha), followed by Gujarat (24 lakh ha) and Telangana (21.14 lakh ha).

Cotton productivity in India remains low due to several constraints such as rainfed conditions, small farm holdings, low-yielding cultivars, sub-optimal plant population, inefficient fertilizer application, and increased pest and disease incidence. Planting density and cultivar choice are critical agronomic practices that can optimize canopy photosynthesis and crop productivity in different cropping systems.

Plant canopy architectural attributes such as size, shape, and orientation of shoot components play a significant role in influencing pest and disease resistance, adaptability, planting density requirements, ease of harvest, and yield potential (Stewart, 2005). Variations in canopy architecture among varieties strongly influence cotton growth, lint yield, and crop management strategies.

The response of cotton varieties with contrasting plant architecture to planting density has important implications for crop management decisions, especially under conditions of high seed cost and technology fees associated with transgenic cotton. Reduced seeding rates, coupled with appropriate variety selection, can significantly modify plant architecture traits, which are genetically governed but agronomically manageable.

Manipulation of plant architectural attributes plays a crucial role in determining cotton growth, yield potential, and crop management practices (Saeed *et al.*, 2011) [9]. Alterations in planting density significantly influence biomass partitioning, nutrient uptake, boll distribution, boll weight, lint yield, changes in the light spectrum, and overall crop productivity, thereby affecting final cotton yield. Productivity can be enhanced by increasing plant population per hectare, i.e., high-density planting. High plant densities help minimize evaporation losses and irrigation frequency, while improving irrigation water use efficiency.

Optimal plant density ensures healthy plant development by maintaining an appropriate core population, synchronizing boll number and fibre quality, ultimately leading to optimal yield (Dong *et al.*, 2010) [4]. In Telangana, farmers commonly cultivate cotton hybrids at spacings of either 90 × 60 cm or 90 × 30 cm**,** without fully exploring the potential benefits of plant architecture-based density management. This approach represents a low-cost agronomic strategy capable of significantly enhancing cotton productivity.

Therefore, the present study was undertaken to assess the influence of different plant densities *vis-à-vis* plant canopy architecture on growth and yield potential of Bt cotton under Telangana agro-climatic conditions.

## 2. Materials and Methods

The field experiment entitled "Influence of plant density *vis-à-vis* architecture on Bt cotton **(***Gossypium hirsutum* L.) yield and quality parameters" was conducted during the kharif seasons of 2021 and 2022 at the College Farm, Professor Jayashankar Telangana State Agricultural University (PJTSAU), College of Agriculture, Rajendranagar, Hyderabad. The experimental site is located at an altitude of 542.3 m above mean sea level**,** at 17°19′ N latitude and 78°23′ E longitude, falling under the Southern Telangana agro-climatic zone**.** The soil texture was sandy loam, slightly alkaline in nature, with organic carbon content of 0.52% in 2021 and 0.51% in 2022.

Initial soil analysis during 2021 revealed low available nitrogen (201.9 kg $ha^{-1}$), high available phosphorus (20.5 kg $ha^{-1}$), and medium available potassium (370.5 kg $ha^{-1}$). During 2022, available nitrogen was 197 kg $ha^{-1}$, phosphorus 21.2 kg $ha^{-1}$, and potassium 361.2 kg $ha^{-1}$.

The average weekly maximum temperature during the crop growth period was 29.4°C during both 2021 and 2022, while the weekly mean minimum temperature was 19.9°C in 2021 and 18.6°C in 2022**.** The total rainfall received was 504.6 mm in 2021 (30 rainy days) and 673.2 mm in 2022 (40 rainy days)**.**

The experiment was laid out in a Split Plot Design with four replications and nine treatment combinations**.** The main plots consisted of three plant types:

- $P_1$: Compact type Bt cotton with Siri (Nuziveedu) hybrid
- $P_2$: Open type Bt cotton with RCH-659 hybrid
- $P_3$: Semi-open type Bt cotton with Sadanand hybrid

Each main plot was subdivided into three sub-plots consisting of plant densities:

- $D_1$: 55,555 plants $ha^{-1}$ (90 × 20 cm)
- $D_2$: 37,037 plants $ha^{-1}$ (90 × 30 cm)
- $D_3$: 18,518 plants $ha^{-1}$ (90 × 60 cm)

The experiment was conducted on the same site for two consecutive years during kharif 2021 and 2022

## 3. Results and Discussion

### Physiological parameters

### 3.1. Leaf Area Index

Data on Leaf Area Index (LAI) as influenced by different plant types and plant densities are presented in Table 1 fig 1. Examination of the data showed that LAI was significantly influenced by both plant type and plant density at all growth stages, except at 30 DAS and for interaction effects**.**

### 3.2. Leaf Area Index as Influenced by Plant Types

The data presented in Table 1 indicate that LAI at 30 DAS was not significantly affected by plant type. However, numerically higher LAI values of 0.63 (2021) and 0.64 (2022**)** were recorded in the semi-open growth type (Sadanand)**,** whereas lower LAI values of 0.55 during both years were observed in the compact type (Siri)**.**

The highest LAI values of 1.93, 3.20, 4.29 and 3.74 (2021) and 1.91, 3.11, 4.39 and 3.75 (2022) at 60 DAS, 90 DAS, 120 DAS, and at harvest**,** respectively, were recorded with the semi-open type (Sadanand)**,** which was statistically on par with the open growth type.

The semi-open plant type (Sadanand) recorded significantly higher Leaf Area Index compared to compact and open types across growth stages. Similarly, higher plant density (90 × 20 cm) consistently produced the highest LAI due to increased leaf area per unit ground area. Interaction effects were significant at 120 DAS**,** indicating that canopy architecture combined with density plays a critical role during peak vegetative growth.

As shown in Table 1 and Fig 1, the semi-open plant type (Sadanand) recorded the highest LAI at all growth stages, indicating better canopy architecture. Data on LAI revealed that at 60, 90, 120 DAS, and at harvest, LAI was significantly influenced by plant densities. At 30 DAS, the effects were non-significant, as seedling development had not yet reached a stage of resource competition. Figure 1 illustrates that LAI consistently increased with crop growth, with the semi-open canopy type maintaining superiority throughout the season.

### 3.3 Influence of Different Plant Densities on Physiological Parameters

The data presented in Table 2 indicate that the semi-open type (RCH-659) was significantly superior to the compact type (Siri) plants. The minimum Leaf Area Index (LAI) values of 1.51, 2.58, 3.72 and 3.14 (2021) and 1.51, 2.48, 3.71 and 3.15 (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest**,** respectively, were recorded under the compact growth type (Siri)**.**

In annual crops, initial leaf area development from seedlings is generally low during early growth stages and differences are often non-significant. As leaf area develops, leaf surfaces expand to capture more sunlight. In the semi-open growth type of cotton**,** leaves are arranged at a specific angle, enabling more effective capture of photosynthetically active radiation and minimizing shading of lower leaves. In contrast, the compact type**,** characterized by an erectophile canopy, exposes less leaf area to direct sunlight, while the open type**,** with a planophile canopy, tends to shade lower leaves.

The semi-open type architecture in Sadanand Bt cotton hybrid exhibited greater light interception, allowing more light penetration into the lower canopy. This enhanced leaf area development resulted in higher assimilate production, better distribution to reproductive structures, and ultimately higher yield. These findings are in agreement with earlier reports by Chapepa *et al.* (2013) [1], Long *et al.* (2017) [5], Chen *et al.* (2021) [2], Chen *et al.* (2022) [3], and Sultana *et al.* (2023) [12].

### 3.4 Effect of Interaction

The interaction effect of plant types × planting densities on LAI was significant at 120 DAS during both individual years and pooled mean.

Interaction data (Table 3) indicated that the highest LAI was recorded under semi-open type (Sadanand) combined with 90 × 20 cm spacing (55,555 plants ha⁻¹) with LAI values of 4.51 (2021), 4.67 (2022), and 4.59 (pooled mean). This treatment was significantly superior to other interaction combinations.

The lowest LAI was observed under compact type (Siri) combined with 90 × 60 cm spacing (18,518 plants ha⁻¹) with LAI values of 3.26 (2021), 3.23 (2022), and 3.25 (pooled mean). This clearly indicates that the semi-open plant type (Sadanand) planted at higher density (90 × 20 cm) resulted in maximum LAI. Similar interaction effects were earlier reported by Mao *et al.* (2014) [7], Chen *et al.* (2022) [3], and Sultana *et al.* (2023) [12].

### 3.5. Specific Leaf Weight (mg cm$^{-2}$)

The data presented in Table 4 indicate that the study shows that SLW was significantly affected by both plant types and plant densities. While individual leaf thickness (SLW) tends to decrease at higher densities due to competition, the semi-open "Sadanand" hybrid maintained significantly higher SLW values (6.12 mg/cm² at 120 DAS) compared to compact types.

Data on specific leaf weight (mg cm$^{-2}$) as influenced by plant types and plant densities are presented in Table 3. The results revealed that specific leaf weight was significantly affected by both plant type and plant density at all growth stages, except at 30 DAS and for interaction effects

**Table 1:** Leaf Area Index of Bt cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types

| Plant Type | 30 DAS (PM) | 60 DAS (PM) | 90 DAS (PM) | 120 DAS (PM) | At Harvest (PM) |
|---|---|---|---|---|---|
| $P_1$ – Siri (Compact) | 0.55 | 1.51 | 2.53 | 3.71 | 3.15 |
| $P_2$ – RCH-659 (Open) | 0.60 | 1.68 | 2.72 | 4.01 | 3.40 |
| $P_3$ – Sadanand (Semi-open) | 0.63 | 1.92 | 3.15 | 4.34 | 3.75 |
| SEm (±) | 0.03 | 0.06 | 0.10 | 0.10 | 0.08 |
| CD (P = 0.05) | NS | 0.23 | 0.40 | 0.37 | 0.32 |

PM = Pooled Mean of 2021 and 2022

NS = Non-significant

**Table 2:** plant densities of Bt cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types and

| Plant Density | 30 DAS (PM) | 60 DAS (PM) | 90 DAS (PM) | 120 DAS (PM) | At Harvest (PM) |
|---|---|---|---|---|---|
| $D_1$ – 90 × 20 cm (55,555 plants ha⁻¹) | 0.65 | 1.98 | 3.22 | 4.38 | 3.75 |
| $D_2$ – 90 × 30 cm (37,037 plants ha⁻¹) | 0.58 | 1.71 | 2.80 | 4.01 | 3.43 |
| $D_3$ – 90 × 60 cm (18,518 plants ha⁻¹) | 0.55 | 1.41 | 2.39 | 3.68 | 3.10 |
| SEm (±) | 0.03 | 0.08 | 0.12 | 0.08 | 0.08 |
| CD (P = 0.05) | NS | 0.25 | 0.38 | 0.24 | 0.24 |

**Table 3:** Interaction Effects

| Interaction | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At Harvest |
|---|---|---|---|---|---|
| P × D | NS | NS | NS | Significant | NSA |

P × D: Interaction of plant type and plant density For two subplot means at the same level of main plot means. For two main plot means at the same level of subplot means

**Table 4:** Leaf Area Index (LAI) of Bt cotton as influenced by plant types (Pooled Mean)

| Plant Type | 30 DAS | 60 DAS | 90 DAS | 120 DAS | Harvest |
|---|---|---|---|---|---|
| Siri (Compact) | 0.55 | 1.51 | 2.53 | 3.71 | 3.15 |
| RCH-659 (Open) | 0.6 | 1.68 | 2.72 | 4.01 | 3.4 |
| Sadanand (Semi-open) | 0.63 | 1.92 | 3.15 | 4.34 | 3.75 |

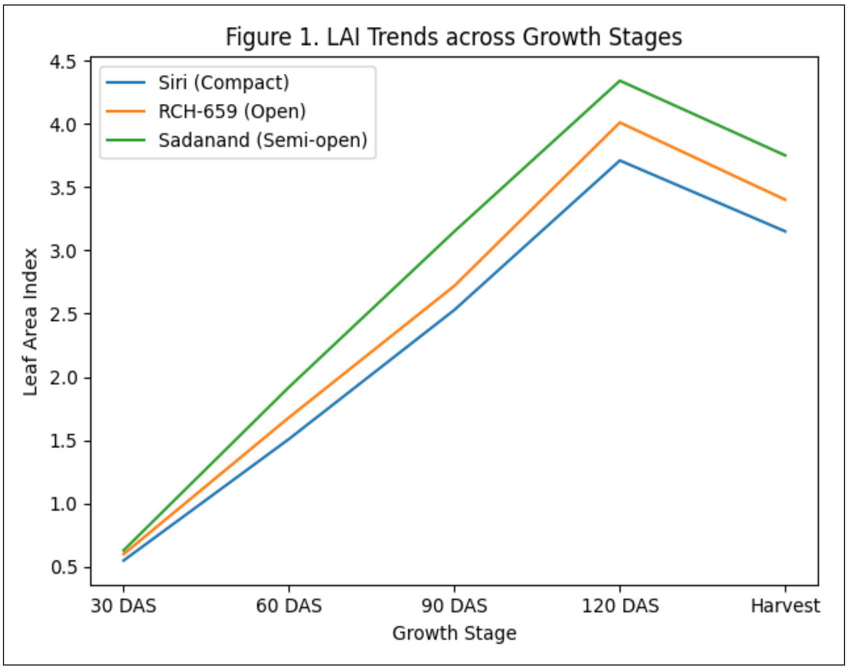


**Fig 1:** Leaf Area Index trends of Bt cotton as influenced by plant types

## 4. Conclusion

The physiological efficiency of Bt cotton is maximized when canopy architecture is matched to planting density. The semi-open hybrid (Sadanand) at a density of 55,555 plants ha$^{-1}$ provides the ideal balance of high leaf area and individual leaf efficiency (SLW). This configuration ensures maximum light interception and optimal biomass partitioning to reproductive structures.

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