



Light interception and yield response of cotton varieties to high density planting and fertilizers in sub-tropical India

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Abstract: Plant density and optimum fertilization are two important agronomic practices to enhance productivity of cotton (*Gossypium hirsutum* L.) varieties. The objective of this study was to investigate the effect of high density planting (HDPS) and fertilization rate, especially their interactions, on yield, yield components of cotton varieties in sub-tropical India. Split-split plot design was adopted and replicated thrice. The main plots were assigned to low, medium and high plant densities (16.7, 13.3 and 11.1 plants/m²). Pre released cotton varieties TCH-1705 and LH-2298 were tested in low, moderate and high rates of fertilizers recommended for the region (100, 125 and 150 %) in sub-sub plots. Significantly higher seed cotton yield (1148 kg/ha) was achieved in narrow inter row spaced at 60 cm over normal plant row spacing of 90 cm (1025 kg/ha). Compact genotype TCH-1705 was out yielded (1146 kg/ha) over LH 2298 (1044 kg/ha). Application of fertilizers at higher rate improved seed cotton yield (1232 kg/ha) Leaf area index (3.8) and light interception (0.98) over blanket recommendation. The results of the study inferred that seed cotton yield improvement was possible under HDPS production system with compact varieties grown at narrow spacing and higher fertilizer dose.

Keywords: Cotton, Leaf area index, Light interception, Plant density

INTRODUCTION

Cotton growing areas of India is characterized by high input responsive, increased cost of production and susceptibility of *Bt*-Cotton hybrids to minor pests. Increasingly, seed costs have become a larger percentage of the overall input costs for cotton production, largely because of the technology development associated with the various transgenic traits (AICCIP Annual Report, 2014).

The adoption of high density planting system (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* cotton growing areas of India. A proper space between plants and row spacing is a key agronomic factor to optimize the resource use and enhance crop productivity. Altered plant density and crop geometry is a time tested agronomic technique to improve yield and profitability (Venugopalan *et al.*, 2013). Establishing an appropriate plant stand is paramount to obtain high yields as lower plant density will be wastage of resources while high plant density limits individual plant growth (Brodrick *et al.*, 2010). Plant density directly influences the radiation interception, moisture availability, wind movement and humidity that in turn affect the canopy height, branching pattern, boll behavior, crop maturity and yield. Adequate plant den-

sity facilitates the efficient use of applied fertilizers and irrigation. A decrease in row width resulted better light interception due to rapid canopy development and early canopy closure. The spirit of cotton crop management is to keep balance between vegetative and reproductive growth. The fertilizer use has played a crucial role in boosting the cotton productivity (Munir *et al.*, 2015).

Light is the key role in net primary productivity, light availability varies with plant population spatial arrangements, especially with canopy structures. The variation in canopy light availability is a result of foliage structural and canopy architectural characteristics (Maddoni *et al.*, 2001). In growing canopies, foliar traits (such as leaf area index and leaf mass per unit area) are the important factors in leaf light harvesting capacity and photosynthetic potentials. Generally, light interception varies with crop developmental stage. Dry matter production is always positively related to light interception.

After introduction of *Bt*-cotton hybrids cotton productivity has jumped four folds in last decade. However, due to susceptibility of *Bt*-cotton to pink bollworm, sucking pests attention has been made towards productivity improvement of cotton varieties. Among many options, seed cotton yield per hectare with enhanced fertilizer dose found profitable and viable (AICCIP Annual Report, 2014). Thus, the field study

was formulated with an objective to investigate determine the impact of canopy on light interception in narrow-wide row planting pattern and performance of cotton varieties under high plant density and graded fertilizer levels.

MATERIALS AND METHODS

Experimental site: Field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Raichur during the rainy season of 2015-16. Experimental site is situated in the North Eastern Dry zone of Karnataka at 16.6° North latitude and 77.3° East longitude with an altitude of 329.6 m above mean sea level. The experiment was laid out in a split-split plot design and replicated thrice. The soil in the experimental site was clay loam with low available nitrogen, medium available phosphorus (12.6 kg/ha) and high available potassium. The treatments consisted of three spacing 60 cm x10 cm (P₁) (16.7 plants/m²), 75 cm x10 cm (P₂) (13.3 plants/m²) and 90 cm x10 cm (P₃) (11.1 plants/m²). Densities were achieved by choosing the appropriate plant distance within a row, thus row distance was maintained. The traditional plant population is 5.5 plants/m². Cotton genotypes TCH-1705 and LH-2298 were selected for the study as sub plot factor. There were three fertilizer levels 100, 125 and 150 per cent of the recommendation as sub-sub plot treatments. For cotton varieties 80:40:40 kg NPK/ha was recommended for the experimental site region. Rest of the production practices were as per the university crop production guide for the region. The row orientation was east to west. Cotton was planted by hand dibbling on 21st August, 2015. Each main plot contained 15, 12 and 10 rows for P₁, P₂ and P₃ respectively rows of cotton, 4 m long with an inter-row spacing of 0.9 m. The harvested at January 15, February and final picking was on 15th February, 2016. A basal fertilizer was applied at a rate of 40 kg N ha⁻¹ and 40 kg ha⁻¹ P

and K and the other half was top-dressed at early flowering and boll initiation stage in two equal splits. The experimental plots were irrigated during dry spells with 50 mm water each time. A top fertilizer with 40 kg ha⁻¹ N was applied at the time of irrigation.

Determination of light interception: Radiation interception is calculated using the following relationship $F = (1 - I/I_0)$ where F is the fractional amount of radiation interception, I_0 is the measured incident PAR on the surface of the ground, and I is the radiant flux density on top of the canopy measured by using a Sun-Scan Canopy analyzer (Delta-T, UK). The value of I_0 was estimated by considering longitude, latitude and sunshine hours as outlined in FAO Irrigation and Drainage Paper No. 56. All measurements were recorded at 10:00 h to 14:00 h in a clear sunny day at intervals of ~7–15 d, from 45 days after planting depending on weather conditions. PAR is assumed to be 0.48 times that of the total solar radiation (Monteith, 1977). The weather data were collected from an automatic weather station near the experimental field. The weather data of daily maximum and minimum temperature, daily incoming solar radiation and rainfall are shown in Fig. 1.

Data analysis: An analysis of variance (ANOVA) was performed using the statistical software OPSTAT. In the analysis, ANOVA was performed to determine treatment differences for effects of plant density, fertilizer, varieties and interaction. Least significant differences (LSD) were used to separate treatment means at the 5% level.

RESULTS AND DISCUSSION

Weather conditions: Environmental parameters including the rainfall, maximum and minimum temperature, and solar radiation during 2015 and 2016 was not much influence on cotton crop growth (Fig. 1.). Daily

Table 1. Seed cotton yield and ancillary data of compact *hirsutum* varieties as influenced by fertilizers and spacings under irrigated condition.

Treatment Details	Plant height (cm)	Monopodia/ plant	Symptodial/ plant	Bolls/ Sq. m	Boll weight (g)	Plant density (No./plot)	Seed cotton yield (kg/ha)
<i>Spacings (S)</i>							
P ₁ : 60 x 10 cm	107.2	1.93	19.0	87.7	3.52	300.9	1148
P ₂ : 75 x 10 cm	115.3	2.09	21.0	72.1	3.61	228.1	1111
P ₃ : 90 x 10 cm	121.2	2.08	23.6	60.5	3.77	151.0	1025
CD (p=0.05)	3.4	NS	0.22	2.6	0.005	2.4	24.1
<i>Varieties (V)</i>							
V ₁ : TCH-1705	101.3	2.04	23.1	77.1	3.74	226.8	1146
V ₂ : LH-2298	117.9	2.02	19.6	69.8	3.54	226.2	1044
CD (p=0.05)	5.6	NS	2.20	3.8	0.01	NS	69.5
<i>Fertilizer doses (F)</i>							
F ₁ : 120:60:60 kg NPK/ha	107.4	1.82	19.4	68.3	3.50	224.1	1005
F ₂ : 150:75:75 kg NPK/ha	112.6	2.03	21.2	73.0	3.55	226.6	1047
F ₃ : 180:90:90 kg NPK/ha	123.7	2.24	23.5	79.0	3.88	228.8	1232
CD (p=0.05)	10.9	0.10	1.87	7.0	0.32	NS	175.8

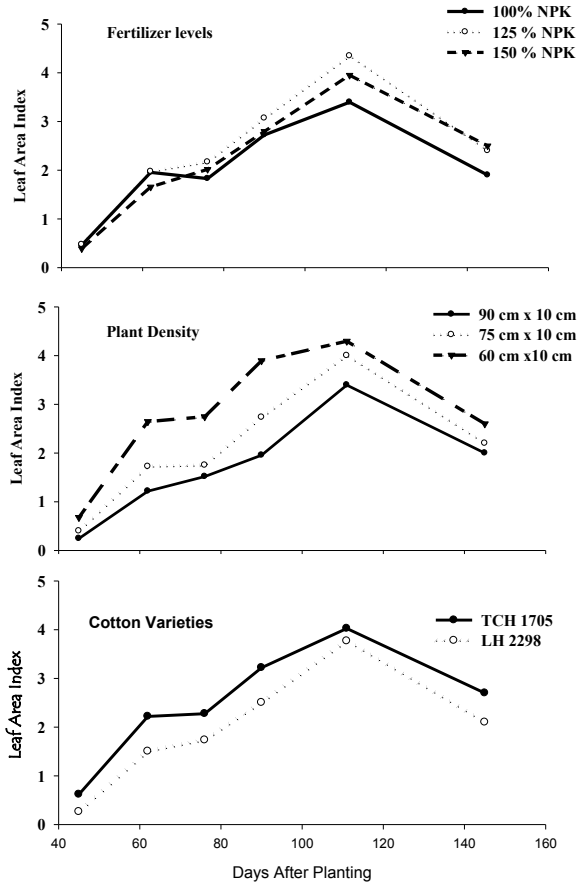


Fig. 1. Leaf area index during growing season under fertilizer supply levels and planting geometry of cotton genotypes in Vertisols.

solar radiation reached a peak of 25 MJ/cm²/day at the summer months and averaged 15 MJ/cm²/day over the growing season. Seasonal precipitation during the experimentation period was similar to normal year. However, rainfall receded abruptly in mid-September and irrigation water available was provided to keep the trial stress free. Planting was delayed due to late onset of monsoon and non-availability of irrigation canal water. Temperature at planting was warm and good for quick establishment and early vigour of cotton crop. Minimum and maximum seasonal temperature trends were similar and followed long term trends.

Plant density: Row spacing is important in crop canopy structure (Andrade *et al.*, 2002; Sharratt and Mc Williams, 2005). Leaf area index (LAI) increases with time; LAI increases until it reach its maximum value, and then it decreases gradually due to leaf senescence. Better canopy structure can result in better solar radiation interception, and consequently affect light availability. In wider spaced plants exhibited taller plants, more number of sympodial per plant, boll weight. However, significantly higher number of bolls per m² and seed cotton yield was recorded in narrow spaced rows (60 cm x 10 cm) over conventional planting pat-

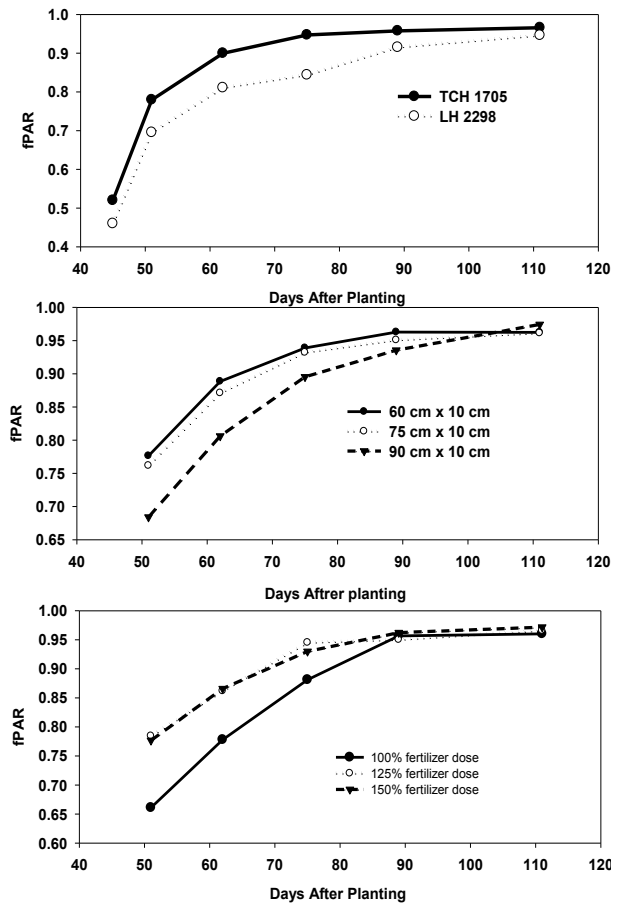


Fig. 2. Fraction of PAR intercepted during growing season under fertilizer levels and planting pattern of cotton varieties in Vertisols.

tern (Table 1). It was mainly due to enhanced light interception and LAI (Fig. 2). Due to higher plant density utilized all natural resources like solar radiation, moisture, nutrients and space. Maximum LAI increased photosynthesis and utilized for boll development, which ultimately improved the seed cotton yield. The taller plants, maximum leaf area index highest seed cotton yield were recorded with high density (2.22 lakh ha⁻¹). Whereas, more sympodial branches, individual boll weight and bolls per plant were increased with decreased plant densities (Paslawar *et al.*, 2015).

Genotypes: An ideal variety having better adaptation to high-density planting is the first step for successful HDPS. On Vertisols, two pre released genotypes were evaluated genotype TCH-1705 was found suitable for HDPS based on growth, yield and yield attributes (Table 1). It also recorded significant differences in sympodial branches, bolls per m², boll weight over LH-2298. Significant increase in yield under high plant densities was higher in dwarf varieties with more determinate growth. Genotype that produce fewer, shorter and lower fruiting branches are ideal for high density planting. TCH-1705 was dwarf and more sympodial

branches and boll weight were responsible for higher seed cotton yield over LH-2298 (Table 1). Silva *et al.* (2012) and Rossi *et al.* (2007) also observed significant interaction between plant density and genotype and recommended a density dependent selection of cotton genotypes. Further, this genotype was also showed higher light interception throughout the crop season indicate better canopy development and utilization of transmitted light (Fig.1). Earlier, Heitholt *et al.* (1996) observed that at equal densities with narrow row allowed each plant to intercept more light and increase seasonal light interception.

Fertilizer levels: A pertinent question to be resolved is whether the demand for nutrients is greater under HDPS since the plant population is higher. Significant difference in seed cotton yield up to 15-18 per cent was recorded by application of 50 per cent higher over blanket recommendation of the region. Singh *et al.* (2012) are of the opinion that application of 25% additional fertilizers would be needed to meet the increased requirement of the crop under HDPS over conventional plant density. Further, Rinehardt *et al.* (2003) also indicated that 30% more N is required under ultra-narrow row cotton compared to the conventional row cotton. The plants grew taller and there was delay in maturity with additional fertilizer dose. Venugopalan *et al.* (2013) opined that application of higher dose of N to high density cotton increased immature bolls and delayed maturity.

Light interception (F): Cumulative intercepted PAR started from emergence up to harvest, which ranged from 14 to 21 MJ m⁻² per day (Fig. 1). The differences in *F* were significant among the planting patterns. In all the planting patterns, *F* consistently increased until 105 days after planting (DAP). During this period, the highest *F* was observed in narrow rowed 60 cm x 10 cm spacing as compared other row patterns. The maximum *F* in P₁, P₂, and P₃ was 0.879, 0.980, and 0.966, respectively. After the canopy closed, the *F* curve began to fit into a slow decline stage. Beyond 128 DAP, the smooth curve did not change for P₂ and P₃ but it fluctuated immediately for P₁. The difference in *F* among the planting patterns was significant the difference in *F* of P₁ from that of the other planting patterns was significant, whereas no significant difference between that of P₂ and P₃ were observed. After 105 DAP until harvest, *F* in P₁ was considerably lower than that in the others. In addition, a remarkably wide bare area between two narrow double rows was observed in P₁; hence, *F* was rather low at noon. In contrast, *F* in P₂ and P₃ was greater at noon.

Leaf area index (LAI): Consistent expansion of cotton LAI over time was throughout the crop season (Fig. 2). For most crops, *F* is highly dependent on LAI. Significant difference among planting patterns, genotypes and fertilizer levels was observed. The maximum LAI was achieved by application of 50 % higher over

blanket recommendation (F1). Application of 100, 125 and 150 percent of blanket was recorded LAI of 3.39, 4.34 and 3.95 respectively. While, narrow spaced canopy recorded significantly higher LAI over wider row spacing at 60 and 90 cm apart. Further, significant difference was observed between cotton genotypes lower LAI was observed in TCH 1705 (4.03) over LH-2298 (3.77). The LAI recorded in P₁, P₂, and P₃ was 3.39, 4.00, and 4.29, respectively. In all planting patterns, once the maximum LAI was attained, the value of LAI started to decline. Moreover, the rate of decline was quite similar across the patterns, cultivars and fertilizer levels.

Conclusion

Weather attributes like temperature, light intensity had not much influence on cotton crop growth. In the present study, high density planting systems (HDPS) in 60 cm inter row spacing and 10 cm within row at a plant density of 16.7 plants/m² was found superior over normal planting production system. With the aid of intensive practices and plant density needs 50 per cent more than recommended dose of fertilizers application was found significant improvement in seed cotton yield. Compact cotton genotype TCH -1705 was out yielded over LH -2298. The results suggest that this HDPS system of cotton production will be successful by selection of potential compact genotype grown in narrow row spacing with application of fertilizers higher than blanket for growing cotton under similar conditions to this experiment.

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