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Light interception, growth and yield of compact cotton as influenced by planting geometry, fertilizer levels and growth retardants under high density planting system

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Abstract

A field experiment was conducted at Department of Agronomy, Agricultural College, UAS, Raichur during 2016-17 and 2017-8 to know the effect of planting geometry, fertilizer levels along with growth retardant spray on light interception, growth and yield of cotton grown under HDPS. The experiment was laid out in split plot design consisting of three levels of planting geometries viz., S₁: 60 cm x 10 cm (1,66,666 plants ha⁻¹), S₂: 75 cm x 10 cm (1,33,333 plants ha⁻¹) and S₃: 90 cm x 10 cm (1,11,111 plants ha⁻¹) in main plots and six levels of fertilizers and growth retardants viz., M₁: 60:30:30 N:P₂O₅:K₂O kg ha⁻¹, M₂: 80:40:40 N:P₂O₅:K₂O kg ha⁻¹, M₃: 100:50:50 N:P₂O₅:K₂O kg ha⁻¹, M₄: M₁ + mepiquat chloride @ 250 ppm sprayed at 60 DAS, M₅: M₂ + mepiquat chloride @ 250 ppm sprayed at 60 DAS and M₆: M₃ + mepiquat chloride @ 250 ppm sprayed at 60 DAS in sub plots. The result revealed that the closer row spacing of 60 cm x 10 cm recorded significantly higher light interception ratio (48.10, 55.46 and 77.83% plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis) while wider row spacing of 90 cm x 10 cm recorded significantly lower light interception ratio (40.08, 48.22 and 70.60% plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis). Closer row spacing of 60 cm x 10 cm produced significantly higher seed cotton yield (2875 kg ha⁻¹) over other planting geometries. Whereas, the growth attributes viz., number of sympodial branches per plant, total dry matter production per plant and absolute growth rate (13.82, 140.14 g and 1.81 g plant⁻¹ day⁻¹, respectively on pooled basis) and yield attributes viz., number of bolls per plant and boll weight (12.74 and 3.68 g, respectively on pooled basis) were significantly higher at a wider row spacing of 90 cm x 10 cm. Among different fertilizer levels, light interception ratio was significantly higher with the application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ (47.40, 58.76 and 82.04% plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis) and significantly lower was observed with the application of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS (44.15 and 65.74% plant⁻¹ at 90 and 120 DAS, respectively on pooled basis). Application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly higher seed cotton yield (2915 kg ha⁻¹). Further, the same treatment recorded significantly higher growth and yield attributing characters. Lower seed cotton yield was recorded with the application of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹ (2392 kg ha⁻¹). Among the different treatment combinations, a treatment combination of closer spacing of 60 cm x 10 cm along with application of higher fertilizer dose of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ recorded significantly higher light interception ratio of 50.53, 61.69 and 85.02 per cent plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis. Interaction of a row spacing of 60 cm x 10 cm along with application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly higher seed cotton yield (3178 kg ha⁻¹) followed by combination of a row spacing of 60 cm x 10 cm along with application of 80:40:40 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS (3031 kg ha⁻¹). While, growth and yield attributing characters were higher under the combination of a row spacing of 90 cm x 10 cm along with application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS.

Keywords: Fertilizer, planting geometry, growth retardant, high density planting system

Introduction

Cotton enjoys a predominant position among all cash crops in India and has retained its unique fame as “King of Fibres” and “White Gold” because of its higher economic value among all cash crops in India.

Bt cotton technology has been widely accepted by the Indian farmers due to inbuilt technology of bollworm management. In spite of heavy inroads of hybrids, especially *Bt* cotton hybrids occupying as much as 95 per cent of the total area under cotton cultivation in India, the seed cotton yield per unit area is still far below than many other cotton growing countries of the world. Among the various factors responsible for low yield of cotton in the country, low plant population and use of low potential varieties are of primary importance.

Under this context, the concept of 'High Density Planting System' (HDPS) in cotton that is ideally suited for both rainfed and irrigated ecosystems has the potential of improving the yield by increasing the plant population by 3 to 4 folds over recommended plant population per hectare. The concept of HDPS is widely adopted by several countries such as China, Brazil, Uzbekistan, Australia, Argentina and several other countries where in plant population of 1,00,000 to 2,00,000 per hectare is maintained and high seed cotton yield of 40 to 50 quintals per hectare is realized. Devi *et al.* (2018) [12] observed significantly higher seed cotton yield (1666 kg ha⁻¹) and stalk yield (7118 kg ha⁻¹) at higher plants density of 60 cm x 10 cm over lower plants densities of 75 cm x 10 cm (1550 kg ha⁻¹ and 6551 kg ha⁻¹, respectively), 90 cm x 10 cm (1356 kg ha⁻¹ and 5914 kg ha⁻¹, respectively) and 90 cm x 45 cm (1173 kg ha⁻¹ and 5454 kg ha⁻¹, respectively). The HDPS cotton not only provides the scope for double cropping and mechanical harvesting but also the added advantages of reducing labour cost with few picking and also farmers will not depend on seed companies for purchase of seeds for sowing every time. Adaption of HDPS along with good fertilizer management under irrigated ecosystem is a viable approach to break the current trend of stagnating cotton yield.

Compact cotton produces excessive vegetative growth under the condition of high rainfall or irrigation with higher fertilizer levels resulting in mutual shading and shedding of reproductive parts there by reducing yield. While, maximizing yield through preventing the excessive vegetative growth during excessive moisture condition, use of growth retardants is required to maintain the suitable plant height of cotton for synchronous boll bursting and mechanical harvesting and this led to the interest in use of plant growth retardants.

Keeping these points in view, field investigation under irrigated condition was carried out to know the light interception, suitable planting geometry, optimum fertilizer level and growth retardant spray to get a sustained higher yield under HDPS system.

Material and Methods

Field experiment entitled "Light interception, growth and yield of compact cotton as influenced by planting geometry, fertilizer levels and growth retardants under high density planting system" Field experiment was carried out at Main Agricultural Research Station Farm, University of Agricultural Science, Raichur which is situated at 16° 12' N latitude and 77° 20' E longitude with an altitude of 389 meter above the mean sea level situated in North Eastern Dry Zone (Zone-2) of Karnataka state. The experiment was conducted on medium black soil, neutral in nature (pH 8.05) with low available nitrogen (219.74 kg ha⁻¹), medium in phosphorus (24.80 kg ha⁻¹) and rich in potassium (374.60 kg ha⁻¹). The mean annual rainfall for past 83 years at the MARS, Raichur was 732.87 mm. The annual rainfall received during experimental period of 2016-17 was 553.2 mm (July to January) which was as equal as normal (552.9 mm). While the rainfall received during experimental period of 2017-18 was 639.5 mm (August to February) which was higher to an extent of 178.7

mm over the normal (460.8 mm). During both the years of study the rainfall was higher than the overall average. During year 2016-17, the peak rainfall distribution was from July to September and during 2017-18 it was from August to October indicating well distribution of rainfall during early period of crop growth. During both the years of experimentation good amount of rainfall was received but it was for short period *i.e.*, up to 60 DAS. Hence, regular irrigation was provided to both the experiments during both the years at later part of crop growth stage *i.e.*, from 60 DAS to till first picking. This facilitated retention of sufficient quantity of soil moisture, which favoured better attributes of growth parameters (plant height, number of monopodial and sympodial branches, leaf area index, total dry matter production *etc.*).

Before the commencement of experiments during both the years the land was ploughed once with mould board plough followed by clod crushing with grubber and harrowing twice to bring the soil to fine tilth. The experiments were laid out as per the plan and small bunds were raised around each experimental unit. Lines were marked in both the ways as per the treatments for spot dibbling. The FYM @ 10 t ha⁻¹ was applied uniformly two weeks before sowing of crop. Different compact cotton genotypes were collected from different sources and used for sowing as per the treatments. The cotton genotypes were sown on 25th July, 2016 during first year and on 4th August, 2017 during second year. A fertilizers dose of 80:40:40 N:P₂O₅:K₂O Kg ha⁻¹ was applied to the experimental plot. Other agronomic operations *viz.*, thinning, plant protection were performed as per the standard package of practice of the state.

Light transmission ratio (LTR) and per cent light interception (LAR): Light interception by the crop canopies was measured at 30, 60, 90, 120 DAS and at harvest by using lux meter. The light intensity received above the canopy of the crop and at ground surface was recorded between 11.30 a.m. and 12:30 p.m. Based on these data, LTR was calculated by the following formula (Yoshida *et al.*, 1972) [12].

$$\text{LTR (\%)} = \frac{I_1}{I_0} \times 100$$

Where,

LTR = Light transmission ratio

I₀ = Light intensity (foot candle) above the canopy

I₁ = Light intensity (foot candle) at ground surface

Per cent light interception (LAR) = 100-LTR

The experiment was laid out in split plot design with three planting geometries *viz.*, S₁: 60 cm x 10 cm (1,66,666 plants ha⁻¹), 75 cm x 10 cm (1,33,333 plants ha⁻¹) and S₃: 90 cm x 10 cm (1,11,111. Plants ha⁻¹) as main plot treatments and six fertilizer levels with growth retardant spray *viz.*, M₁: 60:30:30 N:P₂O₅:K₂O kg ha⁻¹, M₂: 80:40:40 N:P₂O₅:K₂O kg ha⁻¹, M₃: 100:50:50 N:P₂O₅:K₂O kg ha⁻¹, M₄: M₁+ mepiquat chloride @ 250 ppm sprayed at 60 DAS, M₅: M₂ + mepiquat chloride @ 250 ppm sprayed at 60 DAS and M₆: M₃ + mepiquat chloride @ 250 ppm sprayed at 60 DAS as sub plot treatments with three replications.

Results and Discussion

Planting geometries

Among the different planting geometries, A closer spacing of 60 cm x 10 cm recorded significantly higher light interception ratio of 48.10, 55.46 and 77.83 per cent plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis and light interception ratio decreased with increase in spacing and recorded significantly

lower of 40.08, 48.22 and 70.60 per cent plant⁻¹, respectively on pooled basis at wider spacing of 90 cm x 10 cm. Closer spacing reached maximum light interception earlier than wider spacing indicates that greater light interception with the closer spacing leads to more rapid canopy closer than in wider spacing. These results are in line with the findings of Wilson (2006) ^[10], Ajayakumar *et al.* (2017) ^[1] and Udikeri (2017) ^[9]. Significantly higher seed cotton yield (2875 kg ha⁻¹ on pooled basis) was recorded with a closer row spacing of 60 cm x 10 cm. Seed cotton yield was decreased significantly with further increase in row spacing and recorded lowest with the wider spacing of 90 cm x 10 cm (2388 kg ha⁻¹ on pooled basis). Whereas, growth attributing characters viz., number of sympodial branches per plant, total dry matter production per plant and absolute growth rate (13.82, 140.14 g and 1.81 g plant⁻¹ day⁻¹, respectively on pooled basis) and yield attributing characters viz., number of bolls and boll weight (12.74 and 3.68 g, respectively on pooled basis) were significantly higher under wider row spacing of 90 cm x 10 cm. while, other growth parameters viz., crop growth rate and leaf area duration were found significantly higher under closer row spacing of 60 cm x 10 cm (25.51 g m⁻² day⁻¹ and 141.35 days, respectively on pooled basis). The significant increase in the seed cotton yield under the closer row spacing of 60 cm x 10 cm was mainly due to the higher plant population per unit area even though the growth and yield attributes were lower compared to the growth and yield attributes recorded under wider row spacing and due to the fact that increase in plants per unit area could compensated for the decrease in yield components per plant under narrow row spacing. Similar results were also reported by Tuppad (2015) ^[8], Khargkharate *et al.* (2017) ^[5], Parlawar *et al.* (2017) ^[7], Udikeri (2017) ^[9] and Hiwale *et al.* (2018) ^[3].

Fertilizer levels with growth retardant spray

Light interception ratio was also influenced by different fertilizer levels with growth retardant spray. Application of 100:50:50 kg N, P₂O₅ and K₂O kg ha⁻¹ recorded significantly higher LAR of 47.40, 58.76, 82.04 and 58.26 per cent plant⁻¹ at 60, 90, 120 DAS and at harvest, respectively on pooled basis. While, at 60 DAS, it remained at par with application of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS with average LAR of 47.27 per cent plant⁻¹. Whereas, application of 60:30:30 kg N, P₂O₅ and K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly lower LAR of 41.14, 44.15, 65.74 and 45.11 per cent plant⁻¹ at 60, 90, 120 DAS and at harvest, respectively on pooled basis. While, it remained at par with application of 60:30:30 N, P₂O₅ and K₂O kg ha⁻¹ at crop growth stages of 60 DAS with average LAR of 40.95 per cent plant⁻¹. With increase in available nutrient crop growth rate increases which in turn increases the light interception rate. Similar results were also reported by Ajayakumar *et al.* (2017) ^[1] and Udikeri (2017) ^[9]. Significant difference in seed cotton yield was noticed with different fertilizer levels with growth retardant spray. Application of higher fertilizer dose of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly higher seed cotton yield (2915 kg ha⁻¹ on pooled basis), growth attributing characters viz., number of sympodial branches per plant, total dry matter production per plant, absolute growth rate and crop growth rate (12.94, 138.06 g, 1.78 g plant⁻¹ day⁻¹ and 24.05 g m⁻² day⁻¹, respectively on pooled basis) and yield attributing characters viz., number of bolls and boll weight (12.36 and 3.67 g, respectively on pooled basis), while significantly lower seed cotton yield (2392 kg ha⁻¹

on pooled basis), growth attributing characters viz., number of sympodial branches per plant, total dry matter production per plant, absolute growth rate and crop growth rate (10.37, 111.58 g, 1.51 g plant⁻¹ day⁻¹ and 20.52 g m⁻² day⁻¹, respectively on pooled basis) and yield attributing characters viz., number of bolls and boll weight (9.36 and 3.16 g, respectively on pooled basis) were recorded with the application of lower fertilizer dose of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹. Significantly higher seed cotton yield with increased level of fertilizer and growth retardant spray was mainly due to significant increase in growth and yield attributing characters and effective transfer of photosynthates from source to sink. Similar result was also reported by Ikbali *et al.* (2007) ^[4], Tuppad (2015) ^[8] and Malakannavar (2017) ^[6].

Interaction effect

A treatment combination of closer spacing of 60 cm x 10 cm along with application of higher fertilizer dose of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ recorded significantly higher light interception ratio of 50.53, 61.69 and 85.02 per cent plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis. While at 60 DAS, treatment combination of closer spacing of 60 cm x 10 cm along with application of higher fertilizer dose of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS with average light interception ratio of 50.51 per cent plant⁻¹ and at 120 DAS treatment combination of medium spacing of 75 cm x 10 cm along with application of higher fertilizer dose of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ with average light interception ratio of 83.16 remained at par with former treatment combination. Further, treatment combination of wider spacing of 90 cm x 10 cm along with application of lower fertilizer dose of 60:30:30 N, P₂O₅ and K₂O kg ha⁻¹ + mepiquat chloride application @ 250 ppm sprayed at 60 DAS recorded significantly lower light interception ratio of 36.35, 39.99, and 61.50 per cent plant⁻¹ at 60, 90 and 120 DAS, respectively on pooled basis. The results are in line with that of Tuppad (2015) ^[8] and Udikeri (2017) ^[9]. Significantly higher number of sympodial branches, total dry matter production, absolute growth rate, number of bolls and boll weight (14.80 plant⁻¹, 155.99 g plant⁻¹, 192 g plant⁻¹, 15.33 plant⁻¹ and 3.98 g, respectively on pooled basis) were recorded with the treatment combination of wider spacing of 90 cm x 10 cm along with application of higher fertilizer dose of 100:50:50 N, P₂O₅ and K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS. Which was mainly due to the availability of more space and higher level of nutrient availability for individual plant and due to the positive effect of growth retardant. Different treatment combinations influenced significantly on seed cotton yield. Combination of closer row spacing of 60 cm x 10 cm along with the application of higher fertilizer dose of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly higher seed cotton yield (3178 kg ha⁻¹ on pooled basis) and it was found on par with the combination of closer row spacing of 60 cm x 10 cm along with the application of medium fertilizer dose of 80:40:40 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS (3103 kg ha⁻¹ on pooled basis). Whereas, significantly lower seed cotton yield was observed with the combination of wider row spacing of 90 cm x 10 cm along with the application of lower fertilizer dose of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹ (2170 kg ha⁻¹ on pooled basis). These results are in close conformity with the finding of Yasari and Vahed (2012) ^[11], Malakannavar (2017) ^[6] and Udikeri (2017) ^[9].

Table 1: Light absorption ratio (% plant⁻¹) of cotton at 60, 90 and 120 DAS as influenced by agronomic practices under high density planting system

Treatments	Light Absorption Ratio (% Plant ⁻¹)								
	60 DAS			90 DAS			120 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Main plots (S)									
S ₁	49.07 ^a	47.12 ^a	48.10 ^a	56.83 ^a	54.09 ^a	55.46 ^a	79.40 ^a	76.26 ^a	77.83 ^a
S ₂	45.69 ^b	43.85 ^b	44.77 ^b	54.56 ^b	50.87 ^b	52.72 ^b	77.92 ^b	73.23 ^b	75.58 ^b
S ₃	41.08 ^c	39.09 ^c	40.08 ^c	50.35 ^c	46.09 ^c	48.22 ^c	73.60 ^c	67.61 ^c	70.60 ^c
S.E.M±	0.29	0.41	0.08	0.44	0.57	0.33	0.30	0.40	0.35
Sub plots (M)									
M ₁	42.53 ^c	39.37 ^c	40.95 ^c	52.31 ^c	48.25 ^c	50.28 ^c	72.45 ^e	67.16 ^e	69.80 ^e
M ₂	45.58 ^b	43.86 ^b	44.72 ^b	56.87 ^b	53.50 ^b	55.19 ^b	79.13 ^c	74.71 ^c	76.92 ^c
M ₃	47.78 ^a	47.02 ^a	47.40 ^a	60.17 ^a	57.35 ^a	58.76 ^a	83.96 ^a	80.13 ^a	82.04 ^a
M ₄	42.57 ^c	39.72 ^c	41.14 ^c	46.35 ^d	41.94 ^d	44.15 ^d	68.54 ^f	62.94 ^f	65.74 ^f
M ₅	45.24 ^b	43.59 ^b	44.42 ^b	51.97 ^c	48.30 ^c	50.14 ^c	76.18 ^d	71.63 ^d	73.90 ^d
M ₆	48.00 ^a	46.54 ^a	47.27 ^a	55.80 ^b	52.75 ^b	54.28 ^b	81.60 ^b	77.63 ^b	79.61 ^b
S.E.M±	0.60	0.73	0.38	0.64	0.83	0.42	0.64	0.59	0.46
Interactions (S x M)									
S ₁ M ₁	46.75 ^{bc}	43.95 ^{b-e}	45.35 ^c	56.54 ^{b-d}	53.31 ^{b-e}	54.93 ^{cd}	76.22 ^{f-h}	72.35 ^{cd}	74.28 ^{ef}
S ₁ M ₂	49.29 ^{ab}	47.60 ^{a-c}	48.45 ^b	60.07 ^{ab}	57.78 ^{ab}	58.93 ^b	82.05 ^{bc}	79.03 ^b	80.54 ^c
S ₁ M ₃	51.02 ^a	50.05 ^a	50.53 ^a	62.53 ^a	60.86 ^a	61.69 ^a	86.00 ^a	84.05 ^a	85.02 ^a
S ₁ M ₄	47.25 ^{bc}	43.75 ^{b-f}	45.50 ^c	49.81 ^{fg}	45.88 ^{b-h}	47.85 ^f	71.30 ^{ij}	67.03 ^e	69.17 ^h
S ₁ M ₅	48.68 ^{ab}	47.80 ^{ab}	48.24 ^b	54.51 ^{c-e}	51.50 ^{c-e}	53.00 ^{d-e}	78.18 ^{d-g}	74.70 ^c	76.44 ^{de}
S ₁ M ₆	51.44 ^a	49.58 ^a	50.51 ^a	57.51 ^{bc}	55.21 ^{bc}	56.36 ^c	82.69 ^{a-c}	80.40 ^b	81.54 ^{bc}
S ₂ M ₁	43.00 ^{de}	39.82 ^{e-g}	41.41 ^d	52.92 ^{ef}	48.69 ^{e-g}	50.81 ^e	73.41 ^{hi}	67.74 ^e	70.57 ^{gh}
S ₂ M ₂	45.98 ^{b-d}	44.28 ^{b-d}	45.13 ^c	57.60 ^{bc}	53.98 ^{b-d}	55.79 ^c	80.13 ^{c-e}	75.34 ^c	77.73 ^d
S ₂ M ₃	48.13 ^{ab}	47.56 ^{a-c}	47.84 ^b	61.09 ^a	57.93 ^{ab}	59.51 ^b	84.78 ^{ab}	81.53 ^{ab}	83.16 ^{ab}
S ₂ M ₄	42.72 ^{de}	40.42 ^{d-g}	41.57 ^d	46.79 ^g	42.41 ^h	44.60 ^g	69.54 ^{jk}	63.54 ^f	66.54 ⁱ
S ₂ M ₅	45.85 ^{b-d}	43.87 ^{b-e}	44.86 ^c	52.48 ^{ef}	48.83 ^{e-g}	50.66 ^e	77.21 ^{c-g}	72.22 ^{cd}	74.72 ^{ef}
S ₂ M ₆	48.48 ^{ab}	47.13 ^{a-c}	47.81 ^b	56.51 ^{b-d}	53.40 ^{b-e}	54.95 ^{cd}	82.47 ^{bc}	79.00 ^b	80.74 ^{bc}
S ₃ M ₁	37.82 ^f	34.34 ^h	36.08 ^e	47.46 ^g	42.76 ^h	45.11 ^g	67.72 ^{kl}	61.38 ^f	64.55 ⁱ
S ₃ M ₂	41.47 ^e	39.69 ^{fg}	40.58 ^d	52.95 ^{ef}	48.74 ^{e-g}	50.85 ^e	75.23 ^{gh}	69.77 ^{de}	72.50 ^{fg}
S ₃ M ₃	44.20 ^{c-e}	43.47 ^{c-f}	43.83 ^c	56.90 ^{b-d}	53.27 ^{b-e}	55.09 ^{cd}	81.10 ^{cd}	74.80 ^c	77.95 ^d
S ₃ M ₄	37.72 ^f	34.98 ^h	36.35 ^e	42.44 ^h	37.54 ⁱ	39.99 ^h	64.77 ^l	58.23 ^g	61.50 ^j
S ₃ M ₅	41.19 ^e	39.11 ^g	40.15 ^d	48.94 ^g	44.56 ^{gh}	46.75 ^{fg}	73.15 ^{hi}	67.96 ^e	70.56 ^{gh}
S ₃ M ₆	44.08 ^{c-e}	42.92 ^{d-g}	43.50 ^c	53.39 ^{de}	49.65 ^{d-f}	51.52 ^e	79.64 ^{c-f}	73.48 ^c	76.56 ^{de}
S.E.M±	1.04	1.27	0.65	1.12	1.44	0.74	1.04	1.03	0.80

Table 2: Growth attributes of cotton as influenced by agronomic practices under high density planting system

Treatments	Plant height (cm) at harvest			Number of sympodial branches (plant ⁻¹) at harvest			Total dry matter production (g plant ⁻¹) at harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Main plots (S)									
S ₁	132.44 ^a	123.93 ^a	128.18 ^a	10.16 ^c	9.33 ^c	9.74 ^c	115.00 ^c	108.86 ^c	111.93 ^c
S ₂	125.38 ^b	118.07 ^b	121.73 ^b	11.90 ^b	10.92 ^b	11.41 ^b	126.21 ^b	119.27 ^b	122.74 ^b
S ₃	114.09 ^c	107.90 ^c	111.00 ^c	14.22 ^a	13.42 ^a	13.82 ^a	146.22 ^a	134.06 ^a	140.14 ^a
S.E.M±	1.04	1.14	1.25	0.25	0.34	0.18	1.06	0.73	0.78
Sub plots (M)									
M ₁	117.06 ^d	109.11 ^d	113.08 ^e	10.76 ^d	9.98 ^d	10.37 ^d	115.78 ^c	107.38 ^c	111.58 ^c
M ₂	126.43 ^{bc}	119.58 ^{bc}	123.00 ^c	11.67 ^c	10.91 ^c	11.29 ^c	130.96 ^b	122.18 ^b	126.57 ^b
M ₃	134.18 ^a	127.92 ^a	131.05 ^a	12.33 ^{bc}	11.49 ^{bc}	11.91 ^b	141.42 ^a	132.66 ^a	137.04 ^a
M ₄	112.25 ^d	103.78 ^e	108.01 ^f	11.60 ^c	10.80 ^c	11.20 ^c	113.63 ^c	105.70 ^c	109.66 ^c
M ₅	122.80 ^c	115.24 ^c	119.02 ^d	12.69 ^{ab}	11.80 ^{ab}	12.24 ^b	130.87 ^b	122.55 ^b	126.71 ^b
M ₆	131.11 ^{ab}	124.17 ^{ab}	127.64 ^{ab}	13.51 ^a	12.38 ^a	12.94 ^a	142.19 ^a	133.92 ^a	138.06 ^a
S.E.M±	1.77	1.82	1.61	0.29	0.24	0.17	1.61	1.20	1.29
Interactions (S x M)									
S ₁ M ₁	126.83 ^{c-e}	117.83 ^{c-f}	122.33 ^{e-g}	8.93 ^g	8.27 ⁱ	8.60 ^k	104.42 ^{gh}	97.99 ^e	101.20 ^g
S ₁ M ₂	135.33 ^{a-c}	127.31 ^{a-c}	131.32 ^{bc}	9.80 ^{fg}	9.13 ^{hi}	9.47 ^{jk}	117.48 ^{ef}	110.77 ^d	114.13 ^f
S ₁ M ₃	141.96 ^a	134.56 ^a	138.26 ^a	10.27 ^{fg}	9.53 ^{g-i}	9.90 ^j	126.27 ^d	119.59 ^c	122.93 ^e
S ₁ M ₄	120.88 ^{e-g}	111.75 ^{e-h}	116.32 ^{g-i}	9.80 ^{fg}	8.93 ^{hi}	9.37 ^{jk}	100.48 ^h	94.90 ^e	97.69 ^g
S ₁ M ₅	131.21 ^{b-d}	122.18 ^{b-d}	126.69 ^{c-e}	10.73 ^{ef}	9.87 ^{f-h}	10.30 ^{ij}	116.26 ^f	110.03 ^d	113.15 ^f
S ₁ M ₆	138.41 ^{ab}	129.93 ^{ab}	134.17 ^{ab}	11.40 ^{d-f}	10.27 ^{e-h}	10.83 ^{hi}	125.06 ^{de}	119.90 ^c	122.48 ^e
S ₂ M ₁	118.71 ^{e-g}	110.65 ^{e-h}	114.68 ^{g-j}	10.47 ^g	9.67 ^{gh}	10.07 ^{ij}	113.10 ^f	106.26 ^d	109.68 ^f
S ₂ M ₂	127.99 ^{c-e}	121.00 ^{b-e}	124.50 ^{d-f}	11.40 ^{d-f}	10.60 ^{c-g}	11.00 ^{hi}	128.04 ^d	120.68 ^c	124.36 ^e
S ₂ M ₃	135.78 ^{a-c}	129.25 ^{ab}	132.51 ^{a-c}	12.27 ^{c-e}	11.20 ^{d-f}	11.73 ^{gh}	138.08 ^c	130.84 ^b	134.46 ^d
S ₂ M ₄	113.79 ^{gh}	105.42 ^{hi}	109.61 ^j	11.40 ^{d-f}	10.53 ^{e-g}	10.97 ^{hi}	111.12 ^{fg}	104.52 ^d	107.82 ^f
S ₂ M ₅	123.91 ^{d-f}	116.64 ^{d-g}	120.27 ^{e-h}	12.53 ^{cd}	11.47 ^{de}	12.00 ^{fg}	127.66 ^d	121.18 ^c	124.42 ^e
S ₂ M ₆	132.13 ^{b-d}	125.44 ^{a-d}	128.78 ^{b-d}	13.33 ^{bc}	12.07 ^{cd}	12.70 ^{d-f}	139.23 ^c	132.18 ^b	135.70 ^{cd}
S ₃ M ₁	105.63 ^{hi}	98.85 ^{ij}	102.24 ^k	12.87 ^{cd}	12.00 ^{cd}	12.43 ^{e-g}	129.81 ^d	117.89 ^c	123.85 ^e
S ₃ M ₂	115.98 ^{fg}	110.41 ^{i-h}	113.20 ^j	13.80 ^{bc}	13.00 ^{bc}	13.40 ^{cd}	147.35 ^b	135.10 ^b	141.22 ^{bc}
S ₃ M ₃	124.80 ^{d-f}	119.96 ^{b-f}	122.38 ^{e-g}	14.47 ^{ab}	13.73 ^{ab}	14.10 ^{bc}	159.89 ^a	147.56 ^a	153.73 ^a
S ₃ M ₄	102.07 ⁱ	94.17 ^j	98.12 ^k	13.60 ^{bc}	12.93 ^{bc}	13.27 ^{c-e}	129.29 ^d	117.67 ^c	123.48 ^e
S ₃ M ₅	113.30 ^{gh}	106.89 ^{g-i}	110.10 ^j	14.80 ^{ab}	14.07 ^{ab}	14.43 ^b	148.70 ^b	136.42 ^b	142.56 ^b
S ₃ M ₆	122.78 ^{d-g}	117.13 ^{c-f}	119.96 ^{f-j}	15.80 ^a	14.80 ^a	15.30 ^a	162.29 ^a	149.70 ^a	155.99 ^a
S.E.M±	3.07	3.15	2.02	0.49	0.42	0.29	2.78	2.08	2.23

Table 3: Growth attributes of cotton as influenced by agronomic practices under high density planting system

Treatments	Absolute growth rate (g plant ⁻¹ day ⁻¹) at 91-120 DAS			Crop Growth Rate (G m ⁻² day ⁻¹) at 91-120 DAS			Leaf area duration (days) at 91-120 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Main plots (S)									
S ₁	1.60 ^c	1.46 ^c	1.53 ^c	26.71 ^a	24.31 ^a	25.51 ^a	147.98 ^a	134.72 ^a	141.35 ^a
S ₂	1.67 ^b	1.61 ^b	1.64 ^b	22.20 ^b	21.41 ^b	21.81 ^b	131.94 ^b	121.96 ^b	126.95 ^b
S ₃	1.88 ^a	1.74 ^a	1.81 ^a	20.87 ^c	19.35 ^c	20.11 ^c	125.14 ^c	118.13 ^b	121.63 ^c
S.E.M _±	0.01	0.01	0.01	0.19	0.23	0.09	1.03	1.23	0.94
Sub plots (M)									
M ₁	1.59 ^e	1.44 ^e	1.51 ^e	21.53 ^d	19.52 ^c	20.52 ^e	120.45 ^e	112.18 ^d	116.32 ^e
M ₂	1.71 ^d	1.57 ^c	1.64 ^c	23.15 ^c	21.31 ^b	22.23 ^c	142.72 ^c	134.78 ^b	138.75 ^c
M ₃	1.79 ^b	1.69 ^b	1.74 ^b	24.28 ^{ab}	22.82 ^a	23.55 ^{ab}	161.40 ^a	151.35 ^a	156.37 ^a
M ₄	1.62 ^e	1.52 ^d	1.57 ^d	21.98 ^d	20.65 ^b	21.32 ^d	105.09 ^f	94.19 ^e	99.64 ^f
M ₅	1.75 ^c	1.67 ^b	1.71 ^b	23.73 ^{bc}	22.61 ^a	23.17 ^b	130.38 ^d	119.43 ^c	124.90 ^d
M ₆	1.84 ^a	1.73 ^a	1.78 ^a	24.89 ^a	23.22 ^a	24.05 ^a	150.09 ^b	137.69 ^b	143.89 ^b
S.E.M _±	0.02	0.02	0.01	0.26	0.28	0.20	1.90	1.92	1.63
Interactions (S x M)									
S ₁ M ₁	1.48 ^j	1.33 ^j	1.41 ^k	24.68 ^{de}	22.22 ^{c-e}	23.45 ^{c-e}	133.33 ^{e-g}	123.88 ^{e-g}	128.60 ^{ef}
S ₁ M ₂	1.60 ^{ij}	1.44 ^{hi}	1.52 ^{hi}	26.65 ^c	24.02 ^b	25.34 ^b	158.89 ^b	148.49 ^b	153.69 ^b
S ₁ M ₃	1.68 ^h	1.54 ^f	1.61 ^f	28.03 ^{ab}	25.62 ^a	26.83 ^a	178.34 ^a	165.42 ^a	171.88 ^a
S ₁ M ₄	1.50 ^{kl}	1.41 ⁱ	1.46 ^{jk}	25.04 ^d	23.52 ^{b-d}	24.28 ^c	112.82 ^{jk}	98.21 ^{jk}	105.51 ^{hi}
S ₁ M ₅	1.63 ^{hi}	1.55 ^f	1.59 ^{fg}	27.17 ^{bc}	25.83 ^a	26.50 ^a	141.91 ^{cd}	126.55 ^{d-f}	134.23 ^{de}
S ₁ M ₆	1.72 ^{ef}	1.48 ^{gh}	1.60 ^{fg}	28.67 ^a	24.64 ^{ab}	26.65 ^a	162.60 ^b	145.78 ^b	154.19 ^b
S ₂ M ₁	1.55 ^{jk}	1.43 ^{hi}	1.49 ^{ij}	20.65 ^{i-l}	19.10 ^{gh}	19.87 ^{jk}	118.64 ^{ij}	108.82 ^{hi}	113.73 ^{gh}
S ₂ M ₂	1.66 ^{gh}	1.57 ^f	1.61 ^f	22.12 ^{g-j}	20.92 ^{ef}	21.52 ^{g-i}	137.96 ^{d-f}	130.83 ^{c-e}	134.39 ^{de}
S ₂ M ₃	1.73 ^{ef}	1.68 ^{de}	1.71 ^d	23.12 ^{fg}	22.35 ^{c-e}	22.73 ^{d-f}	157.62 ^b	148.07 ^b	152.85 ^b
S ₂ M ₄	1.58 ^{ij}	1.52 ^{fg}	1.55 ^{gh}	21.03 ^{i-k}	20.23 ^{f-g}	20.63 ^{ij}	103.84 ^{lm}	92.27 ^k	98.05 ^{ij}
S ₂ M ₅	1.70 ^{fg}	1.66 ^{de}	1.68 ^{de}	22.70 ^{f-h}	22.17 ^{de}	22.44 ^{e-g}	126.29 ^{gh}	116.52 ^{f-h}	121.41 ^{fg}
S ₂ M ₆	1.77 ^{de}	1.78 ^c	1.77 ^c	23.59 ^{ef}	23.71 ^{bc}	23.65 ^{cd}	147.31 ^c	135.28 ^{cd}	141.29 ^{cd}
S ₃ M ₁	1.73 ^{ef}	1.55 ^f	1.64 ^{ef}	19.26 ^j	17.24 ⁱ	18.25 ^j	109.38 ^{kl}	103.86 ^{ij}	106.62 ^h
S ₃ M ₂	1.86 ^c	1.71 ^d	1.78 ^c	20.68 ^{i-l}	18.98 ^{gh}	19.83 ^{jk}	131.32 ^{fg}	125.01 ^{d-g}	128.16 ^{ef}
S ₃ M ₃	1.95 ^b	1.85 ^b	1.90 ^b	21.69 ^{g-j}	20.50 ^{fg}	21.10 ^{hi}	148.23 ^c	140.57 ^{bc}	144.40 ^c
S ₃ M ₄	1.79 ^d	1.64 ^e	1.71 ^d	19.86 ^{kl}	18.21 ^{hi}	19.04 ^{kl}	98.62 ^m	92.11 ^k	95.36 ^j
S ₃ M ₅	1.92 ^b	1.73 ^c	1.85 ^b	21.32 ^j	19.84 ^{fg}	20.58 ^{ij}	122.95 ^{hi}	115.21 ^{gh}	119.08 ^g
S ₃ M ₆	2.02 ^a	1.92 ^a	1.97 ^a	22.41 ^{i-j}	21.31 ^{ef}	21.86 ^{f-h}	140.37 ^{c-e}	132.01 ^{c-e}	136.19 ^{c-e}
S.E.M _±	0.03	0.03	0.02	0.46	0.48	0.35	2.52	3.31	2.82

Table 4: Yield attributes and yield of cotton as influenced by agronomic practices under high density planting system

Treatments	Number of bolls (plant ⁻¹)			Boll weight (g)			Seed cotton yield (kg ha ⁻¹)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Main plots (S)									
S ₁	9.91 ^c	8.24 ^c	9.08 ^c	3.26 ^c	3.15 ^c	3.21 ^c	3003 ^a	2748 ^a	2875 ^a
S ₂	11.28 ^b	9.98 ^b	10.63 ^b	3.41 ^b	3.29 ^b	3.35 ^b	2836 ^b	2574 ^b	2705 ^b
S ₃	13.49 ^a	11.99 ^a	12.74 ^a	3.75 ^a	3.62 ^a	3.68 ^a	2511 ^c	2266 ^c	2388 ^c
S.E.M _±	0.12	0.21	0.16	0.03	0.02	0.02	32.35	29.97	23.96
Sub plots (M)									
M ₁	10.18 ^c	8.53 ^d	9.36 ^c	3.22 ^d	3.10 ^d	3.16 ^e	2513 ^e	2271 ^e	2392 ^d
M ₂	10.91 ^{bc}	9.56 ^c	10.23 ^b	3.40 ^c	3.27 ^c	3.33 ^d	2715 ^{cd}	2471 ^{cd}	2593 ^c
M ₃	11.44 ^b	10.22 ^{bc}	10.83 ^b	3.48 ^{bc}	3.38 ^{bc}	3.43 ^c	2846 ^{bc}	2586 ^{bc}	2716 ^b
M ₄	11.29 ^b	9.67 ^c	10.48 ^b	3.41 ^c	3.26 ^c	3.33 ^d	2675 ^d	2409 ^d	2542 ^c
M ₅	12.44 ^a	10.82 ^{ab}	11.63 ^a	3.61 ^{ab}	3.50 ^{ab}	3.56 ^b	2904 ^{ab}	2656 ^{ab}	2780 ^b
M ₆	13.09 ^a	11.62 ^a	12.36 ^a	3.72 ^a	3.62 ^a	3.67 ^a	3049 ^a	2782 ^a	2915 ^a
S.E.M _±	0.28	0.33	0.26	0.06	0.05	0.03	54.82	47.10	37.31
Interactions (S x M)									
S ₁ M ₁	8.73 ^h	7.20 ^g	7.97 ⁱ	3.04 ^h	2.93 ^j	2.98 ^j	2695 ^{c-f}	2443 ^{d-f}	2569 ^{gh}
S ₁ M ₂	9.33 ^{gh}	7.87 ^{fg}	8.60 ^{hi}	3.19 ^{gh}	3.07 ^{h-j}	3.13 ^{ij}	2927 ^{b-d}	2678 ^{b-d}	2803 ^{c-f}
S ₁ M ₃	9.73 ^{f-h}	8.20 ^{e-g}	8.97 ^{g-i}	3.26 ^{f-h}	3.15 ^{g-j}	3.21 ^{hi}	3075 ^{ab}	2822 ^{a-c}	2948 ^{b-d}
S ₁ M ₄	9.73 ^{f-h}	7.87 ^{fg}	8.80 ^{hi}	3.21 ^{gh}	3.09 ^{h-j}	3.15 ^{ij}	2879 ^{b-d}	2605 ^{c-e}	2742 ^{d-g}
S ₁ M ₅	10.80 ^{e-g}	8.93 ^{e-g}	9.87 ^{f-h}	3.39 ^{d-g}	3.28 ^{e-i}	3.34 ^{f-h}	3135 ^{ab}	2890 ^{ab}	3013 ^{ab}
S ₁ M ₆	11.13 ^{ef}	9.40 ^{d-f}	10.27 ^{e-g}	3.48 ^{c-g}	3.39 ^{d-g}	3.43 ^{d-g}	3307 ^a	3050 ^a	3178 ^a
S ₂ M ₁	9.93 ^{f-h}	8.33 ^{e-g}	9.13 ^{g-i}	3.16 ^{gh}	3.04 ^{ij}	3.10 ^{ij}	2559 ^{e-g}	2312 ^{f-i}	2436 ^{hi}
S ₂ M ₂	10.67 ^{e-g}	9.33 ^{d-f}	10.00 ^{f-h}	3.33 ^{e-h}	3.22 ^{f-i}	3.28 ^{g-i}	2765 ^{c-e}	2515 ^{d-f}	2640 ^{e-h}
S ₂ M ₃	11.13 ^{ef}	10.07 ^{c-e}	10.60 ^{ef}	3.42 ^{d-g}	3.32 ^{d-h}	3.37 ^{f-h}	2900 ^{b-d}	2630 ^{b-e}	2765 ^{c-g}
S ₂ M ₄	11.00 ^{ef}	9.60 ^{d-f}	10.30 ^{e-g}	3.34 ^{d-h}	3.20 ^{f-i}	3.27 ^{g-i}	2724 ^{c-f}	2453 ^{d-g}	2588 ^{gh}
S ₂ M ₅	12.13 ^{c-e}	11.00 ^{b-d}	11.57 ^{c-e}	3.55 ^{c-f}	3.44 ^{c-f}	3.49 ^{d-f}	2963 ^{bc}	2703 ^{b-d}	2833 ^{b-e}
S ₂ M ₆	12.80 ^{cd}	11.53 ^{bc}	12.17 ^{b-d}	3.66 ^{b-e}	3.56 ^{b-d}	3.61 ^{cd}	3107 ^{ab}	2829 ^{a-c}	2968 ^{bc}
S ₃ M ₁	11.87 ^{de}	10.07 ^{c-e}	10.97 ^{d-f}	3.47 ^{c-g}	3.32 ^{d-h}	3.40 ^{e-g}	2283 ^a	2057 ⁱ	2170 ^j
S ₃ M ₂	12.73 ^{cd}	11.47 ^{bc}	12.10 ^{b-d}	3.66 ^{b-e}	3.53 ^{c-e}	3.59 ^{cd}	2452 ^{e-g}	2220 ^{g-i}	2336 ^{ij}
S ₃ M ₃	13.47 ^{bc}	12.40 ^{ab}	12.93 ^{bc}	3.77 ^{a-c}	3.66 ^{bc}	3.71 ^{bc}	2562 ^{e-g}	2306 ^{f-i}	2434 ^{hi}
S ₃ M ₄	13.13 ^{b-d}	11.53 ^{bc}	12.33 ^{b-d}	3.67 ^{b-d}	3.50 ^{c-e}	3.58 ^{c-e}	2421 ^{fg}	2169 ^{hi}	2295 ^{ij}
S ₃ M ₅	14.40 ^{ab}	12.53 ^{ab}	13.47 ^{ab}	3.90 ^{ab}	3.79 ^{ab}	3.85 ^{ab}	2612 ^{d-f}	2375 ^{e-h}	2494 ^{hi}
S ₃ M ₆	15.33 ^a	13.93 ^a	14.63 ^a	4.03 ^a	3.93 ^a	3.98 ^a	2733 ^{c-f}	2466 ^{d-g}	2600 ^{e-h}
S.E.M _±	0.49	0.57	0.44	0.10	0.08	0.06	94.95	81.59	64.62

Conclusion

Seed cotton yield with 60 cm x 10 cm spacing was maximum (2875 kg ha⁻¹) which was 5.91 and 20.39 per cent higher over 75 cm x 10 cm spacing (2705 kg ha⁻¹) and 90 cm x 10 cm (2388 kg ha⁻¹). Among different fertilizer levels with growth retardant spray, application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS produced significantly higher seed cotton yield (2915 kg ha⁻¹) which was 17.94 per cent higher over application of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹ which recorded significantly lower seed cotton yield (2392 kg ha⁻¹) amongst all other practices. Combination of 60 cm x 10 cm spacing with application of 100:50:50 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS recorded significantly higher seed cotton yield (3178 kg ha⁻¹) and was on par with combination of 60 cm x 10 cm spacing with application of 80:40:40 N:P₂O₅:K₂O kg ha⁻¹ + mepiquat chloride @ 250 ppm sprayed at 60 DAS (3013 kg ha⁻¹) which were 31.71 and 27.98 per cent higher over combination of 90 cm x 10 cm spacing with application of 60:30:30 N:P₂O₅:K₂O kg ha⁻¹ which in turn recorded lowest seed cotton yield amongst all (2170 kg ha⁻¹).

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