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Crop Geometry and Nitrogen Levels Influence on Growth, Yield and Economics of Compact Cotton (*Gossypium hirsutum* L.) in Rainfed Vertisols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To study the effect of crop geometry and nitrogen levels on compact ***cotton genotype*** in rainfed *vertisols* condition.

Study Design: The experiment was laid out in a randomized block design with a factorial concept with 3 levels of crop geometry and four levels of nitrogen with 12 treatment combinations and replicated thrice.

Place and Duration of Study: A field experiment was conducted on *vertisols* under rainfed conditions at Regional Agricultural Research Station Lam, Guntur during the year 2018 – 2019.

Methodology: The treatments consisted of three crop geometries S1 – 60 cm × 10 cm, S2- 75 cm × 10 cm, S3- 90 cm × 45 cm in combination with four nitrogen levels N1- 45kg N ha^{-1}, N2- 90kg N ha^{-1}, N3- 135 kg N ha^{-1}, N4- 180 kg ha^{-1}.

Results: Closer crop geometry of 60 cm × 10 cm recorded taller plants and maximum dry matter accumulation, functional leaves per square meter, leaf area index, maximum chlorophyll content, number of bolls per square meter and seed cotton yield per ha^{-1}, net returns and returns per rupee. However, the number of sympodial branches per plant and sympodial length was highest with wider crop geometry of 90 cm × 45 cm. All the growth and yield parameters recorded were maximum with

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the application of 180Kg N ha^{-1} than all the other levels of nitrogen tested.
Conclusion: Overall, the results showed that the Crop geometry of 60cm × 10 cm with application of 135 kg N ha^{-1} was found to be optimum to realize of maximum seed cotton yield and net returns.

Keywords: Chlorophyll content; compact cotton; crop geometry; high-density planting; nitrogen levels sympodial branches.

1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the most important fibre crop of India and Andhra Pradesh. Cotton occupies a major share among cash crops. It provides the raw material for textile industries, edible oil cake, and surgical cotton. Hence it is known as "white gold" and king of fiber [1].

India occupies the first rank in the area and having the second position in production of seed cotton in the world. In India, cotton is grown predominantly as a rainfed crop total cultivated area in the country is 129.57 lakh hectares with an annual production of 371 lakh bales (170kg) and productivity of 487kg ha^{-1}. In Andhra Pradesh, cotton occupies an area of 5.24 lakh hectares with an annual production of 18 lakh bales and productivity of 584 kg ha^{-1} [2]. However, cotton productivity in India 487 kg ha^{-1} is very low as compared to the world average productivty766 kg ha^{-1}.

In India, although 97% of the cotton area is under transgenic *Bt*. cotton, which has robust growth habit, non-synchronous maturity and required wide spacing, and low plant population per hector which leading to the higher number of seed cotton picking and terminal moisture stress due to its long duration and increased cost of cultivation [3].

Many cotton-producing countries like Brazil, China, Australia, Spain Uzbekistan, Argentina and Greece tested, proved and adopted a narrow row planting system of cotton as a tool to achieve higher productivity [4].

High-density cotton planting system (HDPS) is a new initiative from CICR, Nagpur to improve the productivity and reduction of cost of cultivation by reducing the number of pickings to single picking through conversion from manual picking to machine picking of rainfed cotton in India [5]. The prerequisite for machine picking is HDPS. However, HDPS depends on the availability of compact genotypes with synchronized boll maturity and synchronized boll maturity increase the seed cotton yield and facilitates machine harvesting [6].

Realizing the need for agro techniques for compact cotton varieties, the present experiment is proposed to standardize the agronomic techniques for compact cotton genotype (LHDP1) under high density planting system with graded nitrogen levels with the following objectives.

1. To find out the appropriate planting geometry for optimum growth and yield of cotton.
2. To determine the optimum nitrogen level for cotton.
3. To study the interaction of spacing and nitrogen levels, and
4. To work out the economics.

2. MATERIALS AND METHODS

2.1 Study Area

A field experiment was conducted during *Kharif,* 2018-19 at Regional Agricultural Research Station, Lam, Guntur Andhra Pradesh, India located at an altitude of 31.5m above mean sea level and at the intersection of $16^{0}2'$N latitude and of $80^{0}3'$E longitude.

The experimental soil was classified as clayey in texture, by using the triangular method [7], slightly alkaline in reaction (pH 8.2) by glass electrode method [8], low in organic carbon (0.4%) by Walkley and Black's modified method [9] and available nitrogen (179.6kg ha^{-1}) by alkaline permanganate method [10] high in available phosphorus (46.4kg ha^{-1}) by Olsen's extractant [11] and high in available potassium (638.5kg ha^{-1}) by neutral normal ammonium acetate method [12]. Rainfall received during the crop growth period was 371 mm was received in 22 rainy days and mean evaporation 6mm were recorded during the crop growth period and total rainfall was 25% deficient than the normal rainfall of the region (Fig.1).

The experiment was laid out in a randomized block design with a factorial concept replicated thrice. 'LHDP -1' (Lam high density planting-1) was the test variety. It is a compact variety developed from the Regional Agricultural Research Station suitable for mechanization. The treatments consisted of 3 levels of crop geometry and four levels of nitrogen with 12 treatment combinations viz., three crop geometries of 60cm × 10cm, S2- 75cm × 10cm, S3- 90cm × 45cm in combination with four nitrogen levels N1- 45kg N ha^{-1}, N2- 90kg N ha^{-1},N3- 135kg N ha^{-1},N4- 180kg ha^{-1}.

Nitrogen and potassium applied in three equal splits at 30, 60 and 90DAS and phosphorus at the time of last ploughing and all other cultivation practices followed as per the standard recommendations of the ANGRAU, Guntur.

2.2 Source of Data

All the biometric and yield data collected from the experimental plots treatment wise from all the three replications by using standardized methods of data collection from each treatment.

2.3 Sampling Methods

By using random sampling method selected 15 plants from each treatment for non destructive sampling and tagged the selected plants and recorded data throughout the crop growth period and for destructive samples plants from 3rd and 4th row from border used.

Data related to growth and yield parameters like plant height (cm), dry weights (kg ha^{-1}), monopodial & sympodial branches per plant and sympodial length (cm), number of functional (green) leaves produced per m^2 ,number of bolls per plant and number of bolls per m^2 , bolls weight (grams)as per the standard procedure [13]. SCMR (Spad chlorophyll meter reading) was measured with the Soil Plant Analysis Development meter (SPAD 502 Plus Chlorophyll Meter during active growth stage plants at 90 DAS. Leaf area was estimated by using the automatic leaf area meter, model CI 203, CID Inc.USA. The LAI was computed by using the formula given by [14]. The total seed cotton was harvested in a single picking. Seed cotton was picked from the plants in the net plot area and weighed and expressed in kg ha^{-1}. The net returns and return per rupee investment was worked out as per the standard procedure.

Statistical analysis for the data was done following the analysis of variance technique for Randomized Block design with factorial concept as suggested by [15].

3. RESULTS AND DISCUSSION

3.1 Effect of Crop Geometry on Growth Parameters

The plant height recorded was significantly superior with closer crop geometry of 60cm x10cm (99.6cm) and was significantly superior over 75cm x 10cm and 90 cm x 45 cm at harvest. Dry matter accumulation was recorded highest with closer crop geometry of 60cm × 10cm (8125 kg ha^{-1}) (Table.1) and was significantly superior then other crop geometry tested at harvest. The number of functional leaves per unit area increased with an increase in plant geometry. Closer crop geometry at 60cm x 10cm recorded a higher number of functional leaves per square meter (665) at 90DAS (Table.1). A clear difference in leaf area index was found due to change in crop geometry and it was noted that closer crop geometry of 60cm x 10cm recorded higher LAI (5.8) which was significantly superior over other crop geometry tested at harvest. Zero monopodial branches per plant recorded with narrow crop geometry of 60cmx10cm and 75cmx10cm as compared with wider crop geometry tested. At harvest, the significantly superior number of sympodial branches (23.5) per plant and sympodial branch length (20.6cm) was recorded at wider crop geometry of 90cm × 45cm (Table.1) and it was significantly superior over all the other crop geometry studied. The chlorophyll reading was significantly influenced by different crop geometry tested. Among the various crop, geometry studied 60cm x10cm recorded maximum SCMR (46.2) at 90 DAS and it was significantly superior over the rest of the crop geometry tested. (Table.1). Similar results were reported by [16,17,18,19].

An increase in plant height with closer crop geometry (60cmx10cm) might be due to reduced horizontal space for individual plants and overcrowding which causes interplant compaction for the light which might have lead to an increase in intermodal length and plants grew taller in respect of vertical spaces [20]. The maximum dry matter accumulation, number of functional leaves and leaf area index (LAI) with closer crop geometry might be due to the increased number of plants per unit area thereby more number of leaves per unit area. Higher LAI in closer crop geometry might have enabled the crop to intercept more solar radiation which increased the photosynthetic ability of the crop leading to greater biomass production.. Closer crop geometry recorded zero monopodial and less number of sympodial branches and reduced sympodial branch length might be due to fewer horizontal spaces available, increased competition for resources as compared to wider crop geometry and varietal character [13]. Increased SCMR might be due to increased population per unit area, increased utilization of resources efficiently hence photosynthetic activity got increased.

3.2 Influence of Nitrogen Levels on Growth Parameters

At harvest effect of increased levels of nitrogen on the plant, height was found to be superior with an application of 180 kg N ha^{-1} (97cm) and was on a par with 135 kg N ha^{-1} and 90kg N ha^{-1} and significantly superior with an application of 45 kg N ha^{-1}. (Table.1) Application of 180 kg N ha^{-1} recorded maximum dry matter accumulation (6832 kg ha^{-1}) (Table.1) The functional leaves per square meter (522),LAI (4.8), number of monopodial (0.7) and number of sympodial branches (19.3) per plant, sympodial length (19.6cm) and The SCMR (44.6) and was on a par with an application of 135 kg N ha^{-1} and was significantly superior to all other nitrogen levels tested. (Table.1). These results are in line with results reported by [21,22,23,24]

An increase in growth parameters like plant height, dry matter accumulation, number of functional leaves, LAI, the maximum number of monopodial and sympodial branches, length of sympodial branches at higher levels of nitrogen (135 N kg ha^{-1} and 180kg N ha^{-1}) might be due to more cell division and cell elongation during grand growth period which improved leaf area which made the plants more efficient in photosynthetic activity by improving the carbohydrate metabolism resulting in increased dry matter accumulation and its positive effect on phosphorus and potassium uptake [25]. Increased nitrogen application improved the soil available nitrogen in the rhizosphere which enhanced the uptake of nitrogen further leading to increased chlorophyll formation.

3.3 Effect of Crop Geometry on Yield Attributes, Yield and Economics

At harvest maximum number of bolls per plant (39.6) and boll weight (3.8 g) was recorded with wider crop geometry of 90cm × 45cm than closer crop geometries tested. However, the maximum number of bolls per square meter (186) (Table.2) was recorded with a closer plant spacing of 60cm ×10cm compared with other crop geometry tested. The number of bolls per plant and boll weight was recorded maximum with wider crop geometry might be due to availability of more space for growth and development and more interception of solar radiation and less competition for nutrients and moisture (Table.2). Similar results were reported earlier by [25, 26,27]. However, the number of bolls per square meter was recorded with closer plant spacing due to more number of plants accommodated per unit area. Seed cotton yield (4567kg ha-1), net returns (Rs.1,68,904 ha^{-1}) and return per rupee investment (2.31) (Table.2) was recorded maximum with closer crop geometries of 60cm × 10cm and was superior then other crop geometry tested. Superior yields at closer plant spacing might be due to a higher number of bolls per unit area.

3.4 Influence of Nitrogen Levels on Yield Attributes, yield and Economics

Application of 180kg N ha^{-1} recorded the maximum number of bolls per plant (24.2), the number of bolls per square meter (176.4) and boll weight (3.5g) was significantly superior over all other levels of nitrogen tested. (Table.2), however, boll weight was on par with 135kg N ha^{-1} (3.4g). It might be due to enhanced availability of nitrogen and its positive correlation with other nutrients improved, uptake of nutrients further it improves assimilation of photosynthetic to reproductive parts which lead to increased the dry matter accumulation of plants, it acted as a source to supply nutrients to reproductive parts *i.e.* squares, and bolls. Likewise, more number of bolls and heavier boll weight recorded at higher nitrogen levels could be due to a better source-sink relationship established with a sufficient quantity of nitrogen. These results are in line with results reported by [28,29].

Seed cotton yield (3990kg ha^{-1}), net return (Rs.1,45,085 ha^{-1})and return per rupee (2.2) was recorded highest with an application of 135kg N $ha^{-1}$and it was on a par with 180kg N ha^{-1} (3984 kg ha-1). (Table.2) and was significantly superior over other levels of nitrogen tested. An increase in seed cotton yield with nitrogen application might be due to its favorable effect on plant growth and development, which resulted in increased dry matter accumulation and associated improvement in yield attributing characters. Increased seed cotton yield per unit area leads to maximum net return and return per rupee with increased levels of nitrogen [28].

3.5 Combined Affect Crop Geometry and Nitrogen Levels on Growth and Yield Parameters of Cotton

Interaction effect of crop geometry and nitrogen levels on growth, yield attributes and yield of cotton was found significant for monopodial branches at harvest, SPAD chlorophyll index at 90 DAS and bolls per square meter at harvest.

Wider crop geometry 90cmx45cm crop geometry with the combination of an application of 180 kg N ha^{-1}(2.1) recorded the maximum number of monopodial branches per plant over other combinations tested at harvest. Closer geometry 60cm x10cm along with an application of 180kgN ha^{-1} recorded maximum SCMR values and significantly superior over all the treatment combinations tested. It might be because of efficient use of resources under increased plants per unit area under closer plant geometry and more availability of nitrogen with 180Kg N ha^{-1} for chlorophyll formation. Closer crop geometry of 60cmx10cm with application 180kg N ha^{-1}which recorded the maximum number of bolls per square meter and was superior to other treatment combinations. [30]. It might be due to increased plants per unit area increased number of bolls per unit area even though less retention of bolls per plants and increased availability of nitrogen for increased photosynthesis and improved assimilation to reproductive parts.

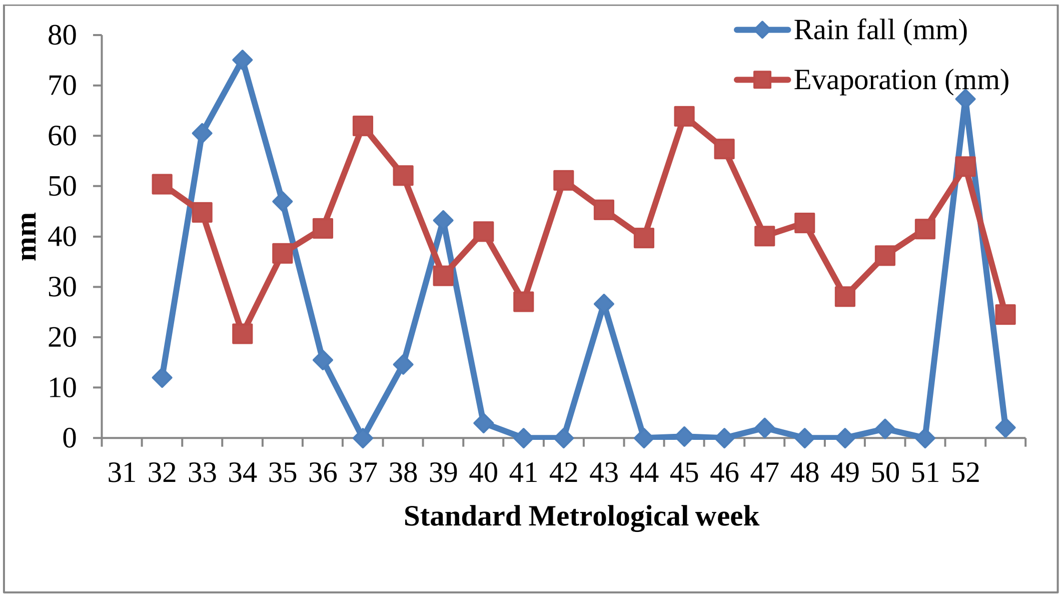

Fig. 1. Weekly mean rainfall (mm) and evaporation (mm) recorded during the crop growth period 2018-19 at Lam, Guntur, AP during 2018-19

Plate 1. a,b,c - An Over view of crop in different crop geometry with growth patern of individual plant at 60 DAS during the crop growth period 2018-19 at Lam, Guntur, AP during 2018-19

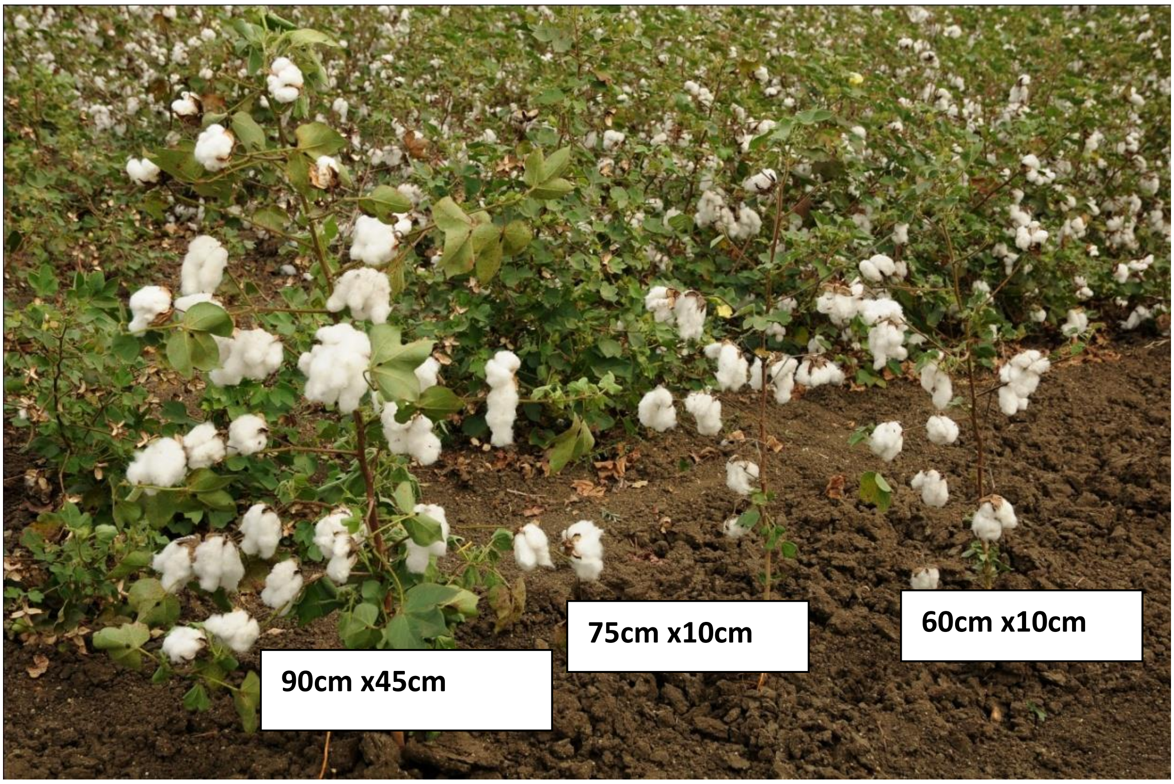

Plate 2. Growth patern of individual plant in different crop geometry at harvest DAS during the crop growth period 2018-19 at Lam, Guntur, AP during 2018-19

Table 1. Influence of crop geometry and nitrogen levels growth parameters of compact cotton of data recorded from experiment conducted at Lam, Guntur, AP during 2018-19

Crop geometry (cm)	Plant height at harvest (cm)	Dry matter accumulation at harvest (kg ha^{-1})	Number of functional leaves at 90 DAS	LAI at harvest	SCMR at 90DAS	Number of monopodial branches per plant	Number of sympodial branches per plant	sympodial length
S_1- 90 X 45	84.5	3969	185	3969	38.8	1.9	23.5	20.6
S_2 - 75 X 10	95.3	7216	627	7216	43.9	0.0	14.9	17.9
S_3 - 60 X 10	99.6	8125	665	8125	46.2	0.0	11.3	15.8
SEm±	2.0	151	8	151	0.4	0.03	0.3	0.5
CD (0.05)	5.8	446	23	446	1.2	0.1	1.0	1.4
Nitrogen levels (Kgha^{-1})								
N_1 -45	87.4	5937	461	5937	35.2	0.6	13.4	16.6
N_2-90	92.7	6311	482	6311	42.6	0.6	15.8	17.4
N_3 -135	95.4	6667	504	6667	43.3	0.7	17.8	18.7
N_4 -180	97.0	6832	522	6832	44.6	0.7	19.3	19.6
SEm±	2.3	174	9	174	0.5	0.03	0.4	0.6
CD (0.05)	6.7	515	27	515	1.4	0.1	1.2	1.6
Interaction (SXN)								
SEm±	3.9	302	16	302	0.8	0.1	0.7	1.0
CD (0.05)	NS	NS	NS	NS	2.4	0.1	NS	NS
CV (%)	7.3	8.1	6	8.1	3.4	10.4	7.1	9.2

Table 2.Influence of crop geometry and nitrogen levels on number of bolls per plant m^2 , Boll weight(g), Seed cotton yield (kgha^{-1}) , net returns and Return per rupee investment of data recorded from experiment conducted at Lam, Guntur, AP during 2018-19

Crop geometry (cm)	Number of bolls per plant at harvest	Number of bolls per seq. meter at harvest	Boll weight (g) at harvest	Seed cotton yield (kgha^{-1})	Net returns(Rs.)	Return per rupee investment (%)
S_1- 90 X 45	39.6	97.7	3.8	2,577	86,087	1.69
S_2 - 75 X 10	13.5	173.0	3.4	4,039	1,47,502	2.19
S_3 - 60 X 10	11.3	186.0	2.9	4,567	1,68,904	2.31
SEm±	0.4	3.3	0.0	77.6	3,336	0.03
CD (0.05)	1.3	9.6	0.1	229	9,847	0.08
Nitrogen levels (Kgha^{-1})						
N_1 -45	18.1	124.8	3.2	3,256	1,14,988	1.9
N_2-90	20.7	144.1	3.3	3,680	1,32,463	2.1
N_3 -135	22.9	163.7	3.4	3,990	1,45,085	2.2
N_4 -180	24.2	176.4	3.5	3,984	1,44,120	2.1
SEm±	0.5	3.8	0.1	89	3,852	0.03
CD (0.05)	1.5	11.1	0.1	264	11,371	0.10
Interaction (SXN)						
SEm±	0.9	6.5	0.1	155.2	6,672	0.06
CD (0.05)	NS	19.2	NS	NS	NS	NS
CV (%)	7.4	7.4	4.5	7.2	9.0	4.0

4. CONCLUSION

Closer crop geometry of 60cm × 10cm recorded increased growth and yield parameters and seed cotton yield in the cotton variety LHDP 1. With increased application of nitrogen from 45 to 180 kg N ha^{-1} growth and yield attributes increased and were maximum with the application of 180kg N ha^{-1}. Seed cotton yield was recorded maximum with 135kg N ha^{-1} which was on a par with 180kg N ha^{-1}. The maximum net returns and return per rupee investment was obtained with the closer spacing of 60cm x10cm with an application of 135kg N ha^{-1}. However, return per rupee investment recorded with existing recommended of 90kg N ha^{-1} also on a par with 135kg N ha^{-1}. Hence inside of conventional wide row planting, high-density planting with compact genotypes with synchronized boll maturity is economically viable in rainfed vertisols and supports to carry out mechanical harvesting to avoid labour shortage problem and improve productivity and overcome the terminal moisture stress problem with high-density planting system.

5. RECOMMENDATIONS

Farmers may adopt closer crop geometry of *60cm × 10cm* with 25% higher nitrogen over recommended dose of nitrogen with compact cotton genotype to increase productivity and reduce the cost of cultivation and overcome labor shortage in rainfed cotton production system in vertisols .

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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