International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

IJBSM March 2023, 14(3):436-442 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR3309a

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3309a

Optimisation of Planting Densities and Nitrogen Requirement for Bt Cotton under High Density Planting System

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ABSTRACT

A field investigation was conducted at College farm, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad, Telangana, India during *kharif* (July to January, 2021–22)to optimise the planting density and nitrogen dose on cotton yield and economics. The experiment was laid out in factorial RBD consisting of four levels of planting densities viz. 90×15 cm^2, 90×20 cm^2, 90×30 cm^2 and 90×60 cm^2 as factor I treatments and 4levels of nitrogenviz., 90, 120, 150,180 kg N ha^{-1} as factor II treatments and replicated thrice. The results revealed that with higher planting density ofspacing 90×15 cm^2 (74,074 plants ha^{-1}) reported significantly higher seed cotton yield (2176 kg ha^{-1}), Gross returns (₹ 1,31,114 ha^{-1}) and net returns (₹ 70,150 ha^{-1}) and was at par with spacing 90×20 cm^2 (55,555 plants ha^{-1}) over other planting density of spacing 90×30 cm^2 (37,037 plants ha^{-1}) and 90×60 cm^2 (18,518 plants ha^{-1}). Lower plant density of spacing 90×60 cm^2 significantly performed better with respect to yield attributes viz, number of picked bolls plant^{-1} (18.2), boll weight (5.1 g) and seed cotton yield (95.0 g plant^{-1}). Among the nitrogen doses, 150 kg N ha^{-1} recorded significantly higher seed cotton yield (2072 kg ha^{-1}), Gross returns (₹ 1,24,818), Net returns (₹ 69,407) and B:C (2.25) over other nitrogen doses tested. However, the interaction effects did not differ significantly for all the parameters studied.

KEYWORDS: Economics, high density planting, nitrogen, seed cotton yield, Telangana

Citation* (VANCOUVER)*: Kavya et al., Optimisation of Planting Densities and Nitrogen Requirement for Bt Cotton under High Density Planting System. *International Journal of Bio-resource and Stress Management,* 2023; 14(3), 436-442. HTTPS://DOI.ORG/10.23910/1.2023.3309a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 17th September 2022 RECEIVED in revised form on 11th February 2023 ACCEPTED in final form on 28th February 2023 PUBLISHED on 19th March 2023

1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.), the most important fibre crop constitutes livelihood for millions of people through cultivation, trade, transportation, ginning and processing (Kumari et al., 2023). The cotton textiles industry is the second largest employer in the country after agriculture, while also sustaining the livelihoods of an estimated 6.5 million cotton farmers (Anonymous, 2022). The Southern zone (which comprises of states like Telangana, Andhra Pradesh, Karnataka, and Tamil Nadu) is the second biggest producer of cotton after central zone, producing about 30% of the nation's cotton, with Telangana producing the largest in the southern zone and the third largest in the country, contributing 6.587 million bales (Anonymous, 2022). It is a fact that cotton is the back bone of textile industry and is the most important commercial crop grown under rainfed conditions of Telangana region. Though, India ranks first in the world cotton production by 2021–22, its productivity levels are very low despite the availability of *Bt* technology. Khan et al. (2019) observed that an expanding population requires global efforts to increase crop production, especially those fulfilling food and clothing needs. On the other hand, high input costs especially higher prices of *Bt* cotton seed (Gadade et al., 2015) coupled with multiple management have threatened cotton productivity. Many cotton producing countries like Brazil, China, Australia, Spain, Argentina and Greece tested, proved and adopted narrow row planting system of cotton as tool to achieve higher productivity (Rossi et al., 2004; Ali et al., 2010).To maintain optimum plant populations the intra-row spacing has to be reduced and short compact genotypes can be grown which produce higher yield at closer intra row spacing as reported by Mert et al. (2006). A proper space between plants and row spacing is a key agronomic factor to optimize the crop profit (Zaxos et al., 2012). In general, it was observed that lower plant densities produce high values of growth and yield attributes per plant, but yield per unit area was higher with higher plant densities (Sharma et al., 2001). Plant competition for resources in higher population resulted in smaller cotton plant with a higher resource use efficiency (Liu et al., 2020) but results in poor boll load and delayed late-season leaf senescence (Luo et al., 2018). Increased plant density would be beneficial to cotton yield in the lower fertility field (Dong et al., 2010; Sankaranarayanan et al., 2018).

Inappropriate planting density, either low or high may exhibit enormous risk for yield formation (Khan et al., 2020).Optimizing plant population is an inexpensive practice that can significantly increase crops production, including castor and cotton (Severino et al., 2012; Li et al., 2020). At present, high density planting system has been suggested as an alternative strategy instead of conventional one to increase yield and it is a time-tested agronomic technique to improve yield profitability and also to improve input use efficiency (Venugopalan et al., 2011; Nalayini and Manickam, 2018). Therefore, establishing an appropriate plant stand is paramount to obtain higher yields as lower plant density will be wastage of resources while, high plant density limits individual plant growth (Brodrick et al., 2013).

The spirit of cotton crop management is to keep balance between vegetative and reproductive growth(Kant et al., 2011). Nitrogen is a key management component in crop production which regulates photosynthesis and development by stimulating the production of dry matter energy rich compounds (Karthik et al., 2022) but its management can reduce final yield and N use efficiency (Rutto et al., 2013). Crop success depends on economically optimum levels of N fertilizers as its deficiency decreased yield by accelerating premature leaf senescence. While, N in excess can delay crop maturity and promoting diseases and pest damages (Wang et al., 2020) and boll shedding as well. The yield potential of the crop can be achieved to maximum only when the nutrient requirements are fully met (Kumari et al., 2022). So, there is a continuous need to find out the optimum nitrogen dose for *Bt-cotton* cultivars in ever changing environment. Thus, the present study was designed to optimise the planting density and nitrogen dose on cotton yield and economics.

2. MATERIALS AND METHODS

The experiment was carried out at College farm, PJTSAU, Rajendranagar, Hyderabad, Telangana, Indiaduring *kharif* (July to January, 2021–22) which is located at 17°19' N latitude and 78°23' E longitude at an altitude of 542.3 m above mean sea level. The soil of the zone is light textured sandy loam with low in available N (197 kg ha^{-1}), medium in available P (21.8 kg ha^{-1}) and organic carbon content (0.52%), high in available K (361 kg ha^{-1}) and pH (7.5) was analysed at Central Instrumentation Cell, PJTSAU. A total rainfall received during the cropping season was 504.6 mm. The experiment was laid out in Factorial Randomised Block Design (FRBD) and replicated thrice. The experiment consists of 16 treatment combinations comprising four plant densities (D$_1$- 90×15 cm^2 (74,074 plants ha^{-1}), D$_2$-90×20 cm^2 (55,555 plants ha^{-1}), D$_3$-90×30 cm^2 (37,037 plants ha^{-1}), D$_4$-90×60 cm^2 (18,518 plants ha^{-1}) in factor I and four levels of nitrogen (N$_1$- 90 kg ha^{-1}, N$_2$-120 kg ha^{-1}$_,$ N$_3$-150 kg ha^{-1}, N$_4$-180 kg ha^{-1}) in factor II. Nitrogen was applied in the form of urea as per treatments in four equal splits at 20, 40, 60, 80 DAS along with recommended dose of potassium and entire quantity of phosphorus was applied basally. All recommended agronomic practices and timely need-based plant protection measures were taken to establish healthy maintenance of crop. The yield observations such as number of bolls plant^{-1}, boll weight (g) and seed cotton yield (kg ha^{-1}) were recorded as per the standard procedure. The data was statistically analysed by adopting standard analysis of variance by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Effect of planting densities and nitrogen doses on yield attributes and yield of Bt-cotton

3.1.1. Boll weight (g)

Boll weight was significantly influenced by planting densities and nitrogen doses. Where, significantly higher boll weight (5.10 g) was recorded with wider spacing of 90×60 cm^2 (18,518 plants ha^{-1}) followed by 90 cm×30 cm(37,037 plants ha^{-1}) (4.82 g) and 90×20 cm^2 (55,555 plants ha^{-1}) spacing (4.56 g). Lower boll weight (4.41 g) was recorded with closer spacing of 90×15 cm^2 and was on par with 90×20 cm^2. A significant increase in boll weight with increasing row spacing was reported by Bhattoo et al. (2011). Jost and Cothren (2001) reported that smaller boll size was due to carbohydrate supply to the bolls was not sufficient to meet the demand of the individual plants under high density planting compared to the conventionally spaced plants. Among nitrogen doses, higher boll weight (4.87 g) was noticed with application of 150 kg N ha^{-1} and was on par with 180 kg N ha^{-1} (4.83 g) and 120 kg N ha^{-1} (4.74 g). The lower boll weight was registered with 90 kg N ha^{-1} (4.45 g). Efficient translocation of photosynthates from source to sink govern the boll weight. Likewise, heavier boll weight at higher nitrogen levels could be due to a better source-sink relationship established with enough nitrogen as reported by Devi et al. (2018).

3.1.2. Number of picked bolls

Greater number of picked bolls plant^{-1} (18.2) were significantly higher with wider spacing of 90×60 cm^2 (18,518 plants ha^{-1})compared to 90×30 cm^2 (37,037 plants ha^{-1}) (11.3) and 90×20 cm^2 (55,555 plants ha^{-1}) spacing (8.9). Lower number of picked bolls plant^{-1} (7.3) was observed with closer spacing of 90×15 cm^2 (74,074 plants ha^{-1}) and was on par with 90×20 cm^2 spacing. Ahmed et al. (2014) reported that number of bolls plant^{-1} increased with increase in plant spacing. Number of bolls plant^{-1} decreased with closer spacing was due to shading of lower leaves and bolls (interplant competition) which resulted in producing unopened bolls and also reduce in transfer of assimilates to reproductive parts. In contrary with this, more number of picked bolls m^{-2} (54.3) were significantly higher with closer spacing of 90×15 cm^2 (74,074 plants ha^{-1}) but was at par with 90×20 cm^2 (55,555 plants ha^{-1}) spacing (49.2) and followed by 90×30 cm^2 spacing (37,037 plants ha^{-1}) (41.7) and 90×60 cm^2 spacing (18,518 plants ha^{-1}) (33.7). The increase in bolls per unit area is due to more number of plants accommodated per unit area. Higher plant densities (74,074 plants ha^{-1}, 55,555 plants ha^{-1} and 37,037 plants ha^{-1}) recorded 61.1, 46.0 and 23.7% boll increase per unit area over lower plant density (18,518 plants ha^{-1}), respectively.

With respect to N doses significantly higher number of picked bolls plant^{-1} (12.9) and number of picked bolls m^{-2} (50.7) was recorded with application of 150 kg N ha^{-1} and was found to be equally effective with application of 180 kg N ha^{-1} and 120 kg N ha^{-1}. Lower number of picked bolls plant^{-1} (9.3) and number of picked bolls m^{-2} (36.7) were observed with application of 90 kg N ha^{-1}. The increase in bolls m^{-2} was due to increase in per plant yield attributes. Enhanced nitrogen level from 150 to 180 kg N ha^{-1} did not influence number of bolls plant^{-1} and unit area which was due to application of higher dose of N, increased hard locks (immature bolls) and delayed maturity was reported by Wiatrak et al. (2000). These results are supported by Jagtap and Bhale (2010).

3.1.3. Seed cotton yield

Yielding ability of a crop was the reflections of yield attributing characters. Seed cotton yield was significantly influenced by planting densities and nitrogen doses. Significantly, higher seed cotton yield (95.0 g plant^{-1}) was obtained from wider spacing of 90×60 cm^2 (18,518 plants ha^{-1}) compared to other closer spacings tested. At closer spacing of 90×15 cm^2 (74,074 plants ha^{-1}) recorded significantly higher seed cotton yield (2176 kg ha^{-1}) over 90×30 cm^2 (37,037 plants ha^{-1}) (1857 kg ha^{-1}) and 90×60 cm^2 spacing (18,518 plants ha^{-1}) (1623 kg ha^{-1}) but was found to be at par with 90×20 cm^2 spacing (55,555 plants ha^{-1}) (2052 kg ha^{-1}). Single plant has greater opportunities to achieve maximum productivity when given ample space to grow, it ultimately resulted in better nourishment and higher seed cotton yield plant^{-1} but these higher values of yield components in wider spacing were compensated through higher plant population per unit area under closer spacings and resulted in higher yields. These results are in agreement with Singh et al. (2012), Nalayini and Manickam (2018) (Table 1).

Among nitrogen doses, higher seed cotton yield (g plant^{-1} and kg ha^{-1}, respectively) (60.3 and 2072) was recorded with application of 150 kg N ha^{-1} compared to 90 kg N ha^{-1} (47.4 and 1706) and was on par with application of 180 kg N ha^{-1} (57.9 and 1996) and 120 kg N ha^{1} (55.8 and 1935).There was linear increase in seed cotton yield from 90–150 kg N ha^{-1} and on further increase i.e., 180 kg N ha^{-1} did not show any positive response on seed cotton yield. This might be due to over use of nitrogen causes excessive vegetative growth, delayed maturity, produces more immature bolls,

Table 1: Influence of planting densities and nitrogen doses on yield and yield attributes of *Bt* cotton

Treatments	Boll weight (g)	No. of picked bolls plant^{-1}	No. of picked bolls m^{-2}	Seed cotton yield (g plant^{-1})	Seed cotton yield (kg ha^{-1})
Planting densities (D)					
D_1: 90×15 cm^2 (74,074 plants ha^{-1})	4.41	7.3	54.3	32.2	2176
D_2: 90×20 cm^2 (55,555 plants ha^{-1})	4.56	8.9	49.2	40.1	2052
D_3: 90×30 cm^2 (37,037 plants ha^{-1})	4.82	11.3	41.7	54.0	1857
D_4: 90×60 cm^2 (18,518 plants ha^{-1})	5.10	18.2	33.7	95.0	1623
SEm±	0.09	0.6	1.8	2.8	65
CD (p=0.05)	0.25	1.6	5.3	8.0	189
Nitrogen doses (N)					
N_1: 90 kg ha^{-1}	4.45	9.3	36.7	47.4	1706
N_2: 120 kg ha^{-1}	4.74	11.5	44.1	55.8	1935
N_3: 150 kg ha^{-1}	4.87	12.9	50.7	60.3	2072
N_4: 180 kg ha^{-1}	4.83	12.0	47.6	57.9	1996
SEm±	0.09	0.6	1.8	2.8	65
CD (p=0.05)	0.25	1.6	5.3	8.0	189
Interaction (D×N)					
SEm±	0.17	1.11	3.7	5.5	131
CD (p=0.05)	NS	NS	NS	NS	NS

increased boll rot and invited more sucking pests which further leads to reduction in yields. These are in line with results of Bibi et al. (2011), Brar et al. (2013), Zhang et al. (2021).The interaction effect of yield parameters and yield was found to be non-significant during the study.

3.2. Economics

The economics of the *Bt* cotton were significantly influenced by planting densities and nitrogen doses. Among planting densities, significantly higher gross (₹ 1,31,114) and net returns (₹ 70,150) were recorded with 90×15 cm^2 spacing but was on par with gross (₹ 1,23,623) and net returns ₹ 66,588) of 90×20 cm^2 spacing. While, higher B:C (2.17) was obtained with spacing of 90×20 cm^2. With application of 150 kg N ha^{-1} recorded significantly higher gross returns (₹ 1,24,818), net returns (₹ 69,407), B:C ratio (2.25) over 90 kg N ha^{-1} but was on par with application of 120 and 180 kg N ha^{-1}. The higher net returns and BC ratio with closer spacing was mainly due to higher plant population and higher seed cotton yield obtained per unit area. Similar results were reported by Gangaiah et al. (2013), Gadade et al. (2015) (Table 2).

Table 2: Economics of Bt cotton as influenced planting densities and nitrogen doses

Treatments	Economics			
	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit cost ratio
Planting densities (D)				
D_1: 90×15 cm^2 (74,074 plants ha^{-1})	60,965	1,31,114	70,150	2.15
D_2: 90×20 cm^2 (55,555 plants ha^{-1})	57,035	1,23,623	66,588	2.17
D_3: 90×30 cm^2 (37,037 plants ha^{-1})	53,105	1,11,909	58,805	2.11
D_4: 90×60 cm^2 (18,518 plants ha^{-1})	49,175	97,796	48,621	1.99
SEm±	-	3934	2541	-
CD (p=0.05)	-	11363	7340	-

Table 2: Continue...

Treatments	Economics			
	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit cost ratio
Nitrogen doses (N)				
N_1: 90 kg ha^{-1}	53,296	1,02,766	49,470	1.92
N_2: 120 kg ha^{-1}	53,880	1,16,599	62,719	2.17
N_3: 150 kg ha^{-1}	55,411	1,24,818	69,407	2.25
N_4: 180 kg ha^{-1}	57,691	1,20,259	62,568	2.08
SEm±	-	3934	2541	-
CD (p=0.05)	-	11363	7340	-
Interaction (D×N)				
SEm±	-	7868	5083	-
CD (p=0.05)	-	NS	NS	-

3.3. Quality parameters

3.3.1. Ginning (%)

A perusal of data recorded on ginning (%) was found to be non-significant among planting densities and nitrogen doses during the study. However, the ginning percentage values varied between 34.13 to 35.80. Ginning percentage was found to increase slightly with increase in fertilizer level as reported by Pandagale *et al.* (2015).

3.3.2. Lint index

Lint index is expressed as weight of the lint obtained per seed of cotton, which gives absolute production of lint per seed on area basis. Scrutiny of data revealed that lint index (Table 3) was significantly influenced by plant densities. Where, significantly higher lint index (6.09) was recorded

Table 3: Fibre quality parameters of Bt cotton as influenced by varied plant densities and nitrogen doses under HDPS

Treatments	Ginning (%)	Lint index	Micronaire (μg inch^{-1})
Planting densities (D)			
D_1: 90×15 cm^2 (74,074 plants ha^{-1})	34.13	5.21	4.23
D_2: 90×20 cm^2 (55,555 plants ha^{-1})	34.41	5.43	4.34
D_3: 90×30 cm^2 (37,037 plants ha^{-1})	35.02	5.79	4.38
D_4: 90×60 cm^2 (18,518 plants ha^{-1})	35.80	6.09	4.40
SEm±	0.62	0.20	0.07
CD (p=0.05)	NS	0.58	NS
Nitrogen doses (N)			
N_1: 90 kg ha^{-1}	34.29	5.30	4.31
N_2: 120 kg ha^{-1}	35.15	5.67	4.28
N_3: 150 kg ha^{-1}	35.25	5.91	4.34
N_4: 180 kg ha^{-1}	34.68	5.63	4.41
SEm±	0.62	0.20	0.07
CD (p=0.05)	NS	NS	NS
Interaction (D×N)			
SEm±	1.24	0.40	0.14
CD (p=0.05)	NS	NS	NS

Micronaire (μg inch^{-1}): Micronaire was not affected by increasing plant densities. This was due to quality parameters are primarily governed by genetic makeup of cotton genotypes. Similar was reported by Dadgale et al. (2014), Nalayini and Manickam (2018) with spacing of 90×60 cm^2 (18,518 plants ha^{-1}) but was on par with 90×30 cm^2 (37,037 plants ha^{-1}) (5.79) and 90×20 cm^2 (55,555 plants ha^{-1}) (5.43). While, significantly lower lint index (5.21) was registered with spacing of 90×15 cm^2 (74,074 plants ha^{-1}) and was on par with 90×20 cm^2 spacing (55,555 plants ha^{-1}). Data revealed that lint index was not significantly influenced by nitrogen doses. Molin and Hugie (2010) reported that the quality parameters were not influenced by the plant densities.

4. CONCLUSION

Optimum planting densities and with application of fertilizer N contributes towards more managed maturity with good crop harvest. On realising the economic assessment of *Bt* cotton from the study it can be concluded that an optimum planting density of 90 cm×15 cm (74,074 plants ha^{-1}) spacing and with application of 150 kg N ha^{-1} can be cultivated for realizing better yield parameters, higher seed cotton yield and monetary returns under rainfed conditions in Southern Telangana region.

5. ACKNOWLEDGEMENT

We thank Professor Jayashankar Telangana State Agricultural University, Hyderabad for financial support.

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