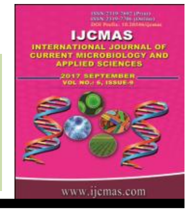
Int.J.Curr.Microbiol.App.Sci (2017) *6*(9): 3199-3207

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 9 (2017) pp. 3199-3207**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2017.609.394

Response of Nitrogen Fertilization and Plant Densities on Bt and Non-Bt Cotton (*Gossypium hirsutum* L.) Hybrids

T. Nagender*, D. Raji Reddy, P. Leela Rani, G. Sreenivas, K. Surekha, Akhilesh Gupta and P.D. Sreekanth

Department of Agronomy, PJTSAU, Rajendranagar, Hyderabad-500 030, Telangana, India
**Corresponding author*

Keywords

Bt cotton, Nitrogen, Harvest index, Seed cotton yield, Plant density.

Article Info

Accepted:
28 August 2017
Available Online:
10 September 2017

A B S T R A C T

A field experiment was conducted during 2015-16 and 2016-17 at Hyderabad to assess the performance of two cotton hybrids of which Bt (MRC 7201 BGII) and non-Bt cotton (WGCV-48) in response to plant densities (P_1: 18,518 plants ha^{-1}, P_2: 55,555 plants ha^{-1} and P_3: 1,48,148 plants ha^{-1}) and nitrogen fertilization (120, 150 and 180 kg ha^{-1}). Among the cultivars during 2015 and 2016, MRC 7201 BG II cultivar recorded significantly more number of bolls plant^{-1} (28, 26), boll weight (5.12, 4.60 g), kapas yield (3497, 2866 kg ha^{-1}), stalk yield (8492, 8193 kg ha^{-1}) and harvest index (32.7, 29.3 %) in comparison to WGCV-48 cultivar, respectively. Among the plant densities, during 2015 and 2016 eventhough the plant density of P_1: 18,518 plants ha^{-1} showed more number of bolls plant^{-1} (42, 40), boll weight (5.16, 5.0 g) and harvest index (43.3, 41.2 %) but the plant density of P_2: 55,555 plants ha^{-1} significantly more kapas yield (3319, 2726 kg ha^{-1}). However, remaining two plant densities P_1: 18,518 plants ha^{-1} and P_3: 1,48,148 plants ha^{-1} were showed comparable yields. While the nitrogen levels did not influence the no. of bolls plant^{-1}, boll weight, ginning per cent, seed cotton yield, stalk yield and harvest index.

Introduction

Cotton is the most important commercial fiber crop of India since time immemorial. Its productivity however, has made little progress since independence. The severe incidence of bollworm complex owes major responsibility for the low cotton productivity in the country. The initial success with 4th generation synthetic pyrethroids in the early 1980's for control of bollworms in cotton was lost with gradual resistance development to these pesticides. The costly and partially successful pest management practices made cotton farming uneconomical. The development of cotton hybrids with a gene from the soil bacterium *Bacillus thuringiensis* (Bt) by Monsanto enabled the plant to produce toxins to defend against bollworms attack. The Bt cotton hybrids were commercialized in USA in 1996 and subsequently introduced to Central and Southern cotton zones of India in 2002 with the grant of permission for cultivation of three Bt cotton hybrids. Subsequently in 2005, six Bt cotton hybrids were approved for cultivation in North cotton zone. Recent region-specific studies in India have found that Bt hybrids improved yields by 45-87 per cent (AICCIP, 2007).

The high density planting system (HDPS) is now being conceived as an alternate production system having a potential for improving productivity and profitability, increasing efficiency, reducing input costs and minimizing risks associated with India's cotton production system. A high density planting system (HDPS) leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges. In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity (Ali *et al.,* 2010). Monsanto has reported a 13-65 per cent rise in yields in Gujarat, while the yields were up 44 per cent in Maharashtra. In Andhra, the yields were up by about 48 per cent. The adoption of HDP, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yield sunder primarily rainfed hirsutum (upland) cotton growing areas. So, a proper space between plants and row spacing is a key agronomic factor to optimize the crop profit (Zaxosa *et al.,* 2012).

Nitrogen, an integral component of many plant compounds such as amino acids, that are the building blocks of proteins, is a vital nutrient for the growth and development of cotton. As N is a mobile element, its deficiency during the early and mid-season results in the chlorosis of older leaves.

Its deficiency also leads to reduced plant height, fruiting branches and increased boll shed (Hodges, 1995). The yield response of Bt cotton (Pettigrew and Adamczyk, 2006) and increases in Bt protein content with N fertilization (Yang *et al.,* 2005) demands adequate N fertilization. The information on comparative performance of Bt and non-Bt cottons under different nitrogen fertilization levels and plant densities in Telangana state of India is lacking. Hence the present study was undertaken to find the response of Bt cotton to different N fertilizer and plant densities for highest yield.

Materials and Methods

These investigations were carried out during *Kharif* 2015-16 and 2016-17 at Agricultural Research Institute, Rajendranagar, Hyderabad situated at an altitude of 542.3 m above mean sea level at 17^{o}19' N latitude and 78^{o}23' E longitude. It is in the Southern Telangana agro-climatic zone of Telangana. According to Troll's climatic classification, it falls under semi-arid tropics (SAT). The experiment was laid out in randomized block design (factorial) replicated thrice with two cultivars (MRC 7201 BG II, WGCV-48) three plant densities (P_1: 18,518 plants ha^{-1} P_2: 55,555 plants ha^{-1} P_3: 1,48,148 plants ha^{-1}) and three nitrogen levels (N_1: 120 kg ha^{-1}, N_2: 150 kg ha^{-1}, N_3: 180 kg ha^{-1}). The soil of the experimental site was sandy loam in texture, neutral in reaction, low in available nitrogen, phosphorus and high in available potassium. During the crop period rainfall of 375.3 mm was received in 27 rainy days in first year and 740.9 mm in 37 rainy days in second year, respectively as against the decennial average of 616.2 mm received in 37 rainy days for the corresponding period indicating 2016-17 as wet year comparatively.

Field was ploughed once with tractor drawn mould board plough followed by cultivator and later with disc harrow. The land within each plot was leveled in order to maintain uniform irrigation water application. Cotton crop was sown on July 8, 2015 and July 7, 2016 by dibbling seeds in opened holes with a hand hoe at depth of 4 to 5 cm as per the spacing in treatments *viz.,* 90 cm X 60 cm, 60 cm X 30 cm and 45 cm X 15 cm. A uniform dose of 60 kg ha^{-1} P_2O_5 as single super phosphate, potassium @ 60 kg ha^{-1} as muriate of potash was applied to all the treatments of Bt cotton cultivar. Entire dose of phosphorus was applied as basal at the time of sowing. Nitrogen was applied as per the treatments (wherever it was required) in the form of urea

(46 % N) in four equal splits (20, 40, 60 and 80 days after sowing (DAS). Similarly, the remaining potassium was applied along with urea in four splits at 20, 40, 60 and 80 days after sowing (DAS) respectively. Whereas, for non *Bt* cotton cultivar uniform dose of 45 kg ha^{-1} P_2O_5 as single super phosphate, potassium @ 45 kg ha^{-1} as muriate of potash was applied to all the treatments. Entire dose of phosphorus was applied as basal at the time of sowing. Nitrogen was applied as per the treatments (wherever it was required) in the form of urea (46 % N) in three equal splits (30, 60 and 90 days after sowing (DAS). Similarly, the remaining potassium was applied along with urea in 3 splits at 30, 60 and 90 days after sowing (DAS) respectively.

Pre emergence herbicide pendimethalin @ 2.5 ml l^{-1} was sprayed to prevent growth of weeds. Post emergence spray of quizalofop ethyl 5% EC @ 2 ml l^{-1} and pyrithiobac sodium 10% EC @ 1 ml l^{-1}. Hand weeding was carried out once at 35 DAS. First irrigation was given immediately after sowing of the crop to ensure proper and uniform germination. Later irrigations were scheduled uniformly by adopting climatological approach *i.e.*, IW/CPE ratio of 0.80 at 5 cm depth. During crop growing season sucking pest incidence was noticed. Initially at 25 DAS spraying of monocrotophos @ 1.6 ml l^{-1} was done. During later stages, acephate @ 1.5 g l^{-1} and fipronil @ 2 ml l^{-1} were sprayed alternatively against white fly and other sucking pests complex during the crop growth period as and when required. For controlling boll worms in non Bt cultivar, monocrotophos @ 1.6 ml l^{-1} and emamectin benzoate 5 % SG @ 0.5 g l^{-1} was sprayed based on the infestation whenever required.

The number of opened bolls on five labeled plants from net plot were counted at each picking, averaged and expressed plant^{-1}. Harvested bolls of each picking from labeled plants of each treatment was weighed, averaged and expressed as boll weight in g boll^{-1}. The cumulative yield of seed cotton from each picking in each treatment from net plot was weighed and expressed in kg ha^{-1}. The lint obtained from each plant was weighed and the ginning was worked out by the formula given below (Khan *et al.*, 2010).

$$\text{Ginning (\%)} = \frac{\text{Lint yield (Fiber)}}{\text{Seed cotton yield (Fiber+ Seeds)}} \times 100$$

Harvest index is defined as the ratio of economic yield to the total biological yield. It is calculated by using the formula given by Donald (1962).

$$\text{Harvest index} = \frac{\text{Seed cotton yield (kg ha}^{-1}\text{)}}{\text{Biological yield (seed cotton yield + stalk yield kg ha}^{-1}\text{)}}$$

Data on different characters *viz*., yield components and yield, were subjected to analysis of variance procedures as outlined for randomized block design, factorial concept (Gomez and Gomez, 1984). Statistical significance was tested by F–value at 0.05 level of probability and critical difference was worked out wherever the effects were significant.

Results and Discussion

Number of bolls plant^{-1}

Data pertaining to number of bolls plant^{-1} with different cultivars at various plant densities and nitrogen levels were analysed statistically and furnished during 2015 and 2016 in Table 1. More number of boll plant^{-1} (28, 26) was noticed with MRC 7201 BGII cultivar and was significantly superior over WGCV-48 cultivar (21, 20) during 2015 and 2016 respectively. Number of bolls plant^{-1} was significantly higher with MRC 7201 BGII cultivar and it induced higher number of flowers and bolls plant^{-1}. These results are in line with earlier findings of Manjunatha *et al.*, (2010). Perusal of data indicated that, the trend was similar during both the years of study at different plant densities. The highest number of bolls plant^{-1} was recorded with P_1: 90 cm x 60 cm (18,518 plants ha^{-1}) which was however, significantly superior to P_2: 60 cm x 30 cm (55,555 plants ha^{-1}) and P_3: 45 cm x 15 cm (1,48,148 plants ha^{-1}). In turn, P_1 produced significantly more number of bolls plant^{-1} (42, 40) over P_3 which registered the lowest number of bolls plant^{-1} (8, 8) during 2015 and 2016, respectively.

In general, low density stands set more of their bolls on second and third positions and on vegetative branches. Bolls tend to be larger in low density stands due to the fact that plants retain and mature a higher per cent of their squares when planted at low densities because light penetration to the leaves that feed young bolls is increased.

On the other hand, when plants were grown wide apart, due to availability of more nutrients and ample space it is a common feature to have more number of bolls.

The higher bolls plant^{-1} was at wider spacing attributed to more available space and nutrients to plants at lower densities. These results were in accordance with the findings of Reddy and Gopinath (2008), Aruna and Reddy (2009), Bhalerao and Gaikwad (2010).

Boll weight (g)

Data pertaining to boll weight (g) under varied plant densities and nitrogen levels for two different cultivars was statistically analysed and furnished in Table 1 during period of the study.

Significantly higher boll weight of cotton (5.12, 4.60 g) was noticed with MRC 7201 BGII cultivar and was significantly superior over WGCV-48 cultivar (4.89, 4.10 g) during 2015 and 2016 respectively. The increase in the yield attributing characters such as boll weight with respect to MRC 7201 BGII cultivar might be due to significantly higher growth components and higher amount of dry matter accumulation in reproductive parts.

These results are in line with earlier findings of Manjunatha *et al.*, (2010). Inbuilt resistance to boll worms and early maturing character was observed in case of Bt hybrid which helped to retain more number of bolls by avoiding its exposure to unfavourable weather condition during peak period of growth that may commence probably during later stages. Utilization of more photosynthates for the nourishment to bolls favouring reproductive growth could be the key physiological phenomenon in Bt cotton resulted into more weight of boll (Patel *et al.*, 2015).

During 2015, higher boll weight (5.16 g) was observed with P_1: 90 cm x 60 cm (18518 plants ha^{-1}) and which is on par with P_2: 60 cm x 30 cm (55555 plants ha^{-1}) (5.02 g) and was significantly superior over P_3: 45 cm x 15 cm (148148 plants ha^{-1}) (4.84 g) while in 2016, significantly higher boll weight (5.00 g) was observed with P_1: 90 cm x 60 cm (18518 plants ha^{-1}) which is superior over P_2: 60 cm x 30 cm and P_3: 45 cm x 15 cm. P_2: 60 cm x 30 cm (4.02 g) and P_3: 45 cm x 15 cm (4.00 g) were on par with each other.

Reductions in plant to plant spacing decreased boll weight due to intense competition for nutrients, water and light at higher plant density (Ogola *et al.*, 2006). However, Bednarz *et al.*, (2000) accredited decreased boll set and weight due to combined effect of excessive LAI, reduced PPFD (photosynthetic photon flux density) efficiency, and reduced mean NAR at higher plant population.

Table.1 Yield attributes and yield of cotton as influenced by cultivars, plant densities and nitrogen levels

Treatments	No. of boll plant^{-1}		Boll weight (g)		Ginning (%)		Seed cotton yield (kg ha^{-1})		Stalk yield (kg ha^{-1})		HI (%)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Factor 1 (Cultivars)												
V_1 (MRC 7201 BGII)	28	26	5.12	4.60	32.6	32.8	3497	2866	8492	8193	32.7	29.3
V_2 (WGCV-48)	21	20	4.89	4.10	34.2	33.1	2510	2078	8162	7507	27.0	25.7
S.Em±	0.58	0.69	0.06	0.10	0.62	1.27	74	49	98	158	0.54	0.52
CD (P=0.05)	1.66	1.98	0.16	0.39	NS	NS	214	141	282	455	1.55	1.50
Factor 2 (Plant densities)												
P_1 (90 cm X 60 cm)	42	40	5.16	5.00	32.6	34.3	2738	2309	3526	3288	43.3	41.2
P_2 (60 cm X 30 cm)	22	21	5.02	4.20	33.3	30.8	3319	2726	8644	8145	27.5	24.9
P_3 (45 cm X 15 cm)	8	8	4.84	4.00	34.2	33.7	2954	2381	12811	12117	18.6	16.4
S.Em±	0.71	0.84	0.07	0.16	0.76	1.56	91	60	120	194	0.66	0.64
CD (P=0.05)	2.03	2.43	0.20	0.47	NS	NS	261	173	345	557	1.90	1.83
Factor 3 (Nitrogen levels)												
N_1 (120 kg N ha^{-1})	24	23	5.01	4.50	33.0	32.2	2946	2383	8540	7874	29.3	26.7
N_2 (150 kg N ha^{-1})	24	23	5.00	4.40	33.5	35	2962	2528	8181	7800	29.9	28.1
N_3 (180 kg N ha^{-1})	25	23	5.01	4.30	33.7	31.7	3102	2505	8260	7876	30.3	27.6
S.Em±	0.71	0.84	0.07	0.16	0.76	1.56	91	60	120	194	0.66	0.64
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The present results were in conformity with results of Dong *et al.*, (2010), where high plant density reduced the boll weight relative to low plant density.

Ginning per cent

Data pertaining to ginning per cent during both years under varied plant densities and nitrogen levels for two different cultivars were analysed statistically and furnished in table 1 during period of investigation. Cultivars, nitrogen (N) levels and plant densities did not influence the ginning per cent of the cotton, while interactions were not found statistically significant during both years of the study.

Seed cotton yield (kg ha^{-1})

Experimental data on seed cotton yield was analysed statistically and found significantly influenced by different nitrogen levels and plant densities for two cultivars Table 1.

The response due to variation in cultivars was similar in both years of study. The highest seed cotton yield (3497 and 2866 kg ha^{-1}) was obtained with MRC 7201 BGII cultivar and was significantly superior to WGCV-48 cultivar (2560 and 2078 kg ha^{-1}). The rate of increase in seed cotton yield with V_1 was 28 and 27 % during 2015 and 2016 over V_2 respectively.

Higher seed cotton yield was evidently due to cumulative effect of more number of bolls/plant and boll weight in Bt hybrid than non Bt. The better performance of MRC 7201 BGII cultivar over WGCV-48 cultivar was ascribed to higher boll numbers plant^{-1} and heavier boll weight and the superior performance of Bt hybrids might be also due to inbuilt resistance to boll worms by Bt gene which in turn might have caused Bt hybrids to move in to reproductive phase early by curtailing vegetative growth and helped to produce higher seed cotton yield (Aruna, 2016).

Significantly higher seed cotton yield (3319 and 2726 kg ha^{-1}) was obtained in P_2: 60 cm x 30 cm (55555 plants ha^{-1}) over P_3: 45 cm x 15 cm (148148 plants ha^{-1}) and P_1: 90 cm x 60 cm (18518 plants ha^{-1}), while P_3 (2954 and 2381 kg ha^{-1}) and P_1 (2738 and 2309 kg ha^{-1}) are comparable and on par with each other. The per cent increase of seed cotton yield in P_2 11, 13 % and 17, 15 % during 2015 and 2016 over P_3 and P_1 respectively.

The ultimate seed cotton yield is the manifestation of yield contributing characters. These yield attributing characters were significantly affected by different plant populations. Even though, the boll number, boll weight and seed cotton yield plant^{-1} were significantly higher with wider spacing, it could not compensate for the loss in number of plants ha^{-1} and number of bolls m^{-2}, thus recorded lower seed cotton yield ha^{-1} when compared to high density planting. Higher plant density at closer spacing recorded significantly higher seed cotton yield than lower plant density at wider spacing due to significantly more number of bolls m^{-2} and higher plant stand ha^{-1} (Kalaichelvi, 2009, Krishnaveni *et al.*, (2010), Manjunatha *et al.*, (2010) and Brar *et al.*, 2013).

Stalk yield (kg ha^{-1})

Data on stalk yield (kg ha^{-1}) analysed statistically and was significantly differed due to plant densities, nitrogen levels and cultivars Table 1.

Results revealed that, stalk yield decreased with WGCV-48 cultivar in both the years of study as that seen in seed yield compared to MRC 7201 BGII cultivar. The highest stalk yield (8492 and 8193 kg ha^{-1}) was noticed with MRC 7201 BGII cultivar and significantly superior to WGCV-48 cultivar (8162 and 7507 kg ha^{-1}). The increase in stalk yield with V_1 was 3 and 8 per cent during 2015 and 2016 respectively over V_2. Higher stalk yield pertaining to MRC 7201 BGII cultivar may be attributed to the improvement in the assimilation of photosynthates and their accumulation in leaves and stem at various stages of crop growth. These results were in close agreement with findings of Manjunatha *et al.,* (2010) and Shukla *et al.,* (2013).

Stalk yield increased consistently with increasing plant densities during both the years of study. The highest stalk yield (12811 and 12117 kg ha^{-1}) was recorded with P_3: 45 cm x 15 cm (148148 plants ha^{-1}) over P_2: 60 cm x 30 cm (55555 plants ha^{-1}) and P_1: 90 cm x 60 cm (18518 plants ha^{-1}). The lowest stalk yield was observed with P_1: 90 cm x 60 cm (3526 and 3288 kg ha^{-1}). The rate of increase in stalk yield with P_3 over P_2 and P_1 was 33, 33 % and 72, 73 % during 2015 and 2016 respectively. The increased stalk yield at higher density might be due to increased plant population per unit area (Dong *et al.,* 2012).

Harvest Index (HI)

Harvest index shows the physiological efficiency of plants to convert the fraction of photo assimilates to seed yield. The appraisal of the data on harvest index as influenced by different cultivars, plant densities and nitrogen levels was presented in Table 1.

During 2015 and 2016, higher harvest index (32.7, 29.3 %) was obtained for MRC 7201 BGII cultivar followed by WGCV-48 cultivar (27.0, 25.7 %) respectively. Among the different plant densities the highest harvest index (43.3, 41.3 %) was obtained in P_1: 90 cm x 60 cm (18518 plants ha^{-1}) and it was followed by P_2: 60 cm x 30 cm (55555 plants ha^{-1}) and P_3: 45 cm x 15 cm (148148 plants ha^{-1}). The lowest harvest index (18.6 and 16.4 %) was obtained in P_3 during 2015 and 2016 respectively.

High plant density produced the greatest biological yield but the lowest harvest index. Although high plant density increase total plant biomass per unit ground area (biological yield), final reproductive allocation as indicated by harvest index was usually reduced by increased plant density because of luxurious vegetative growth and lower lint yield (Ali *et al.,* 2009). The increased plant density delayed the leaf senescence due to improved leaf photosynthesis, but significantly reduced the boll load. There was a significant negative correlation ($r = -0.8014$) between boll load and leaf senescence at the onset of boll opening (Dong *et al.,* 2012).

No. of bolls $plant^{-1}$, boll weight, ginning percent, seed cotton yield, stalk yield and harvest index were not influenced by the different levels of nitrogen during both the years of study. Interaction effect of cultivars and plant densities, plant densities and nitrogen levels, nitrogen levels and cultivars, and cultivars, plant densities and nitrogen levels did not exert significant influence on no. of bolls $plant^{-1}$, boll weight, ginning percent, seed cotton yield, stalk yield and harvest index of cotton crop during both years of study.

During 2015 and 2016, MRC 7201 BG II cultivar recorded significantly more number of bolls $plant^{-}$1, boll weight, kapas yield, stalk yield and harvest index in comparison to WGCV-48 cultivar. Among the plant densities, even though, the plant density of P_1: 18,518 plants ha^{-1} showed more number of bolls $plant^{-1}$, boll weight and harvest index but the plant density of P_2: 55,555 plants ha^{-1} significantly more kapas yield. However, remaining two plant densities P_1: 18,518 plants ha^{-1} and P_3: 1,48,148 plants ha^{-1} were showed comparable yields.

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How to cite this article:

Nagender, T., D. Raji Reddy, P. Leela Rani, G. Sreenivas, K. Surekha, Akhilesh Gupta and Sreekanth, P.D. 2017. Response of Nitrogen Fertilization and Plant Densities on Bt and Non-Bt Cotton (*Gossypium hirsutum* L.) Hybrids. *Int.J.Curr.Microbiol.App.Sci.* 6(9): 3199-3207.
doi: https://doi.org/10.20546/ijcmas.2017.609.394