International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 249-252

Received: 10-03-2020
Accepted: 12-04-2020

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Effect of nutrient fortification and spacing on growth and yield of *Bt* cotton under protective irrigation

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3d.9235

Abstract
The field experiment was conducted in *Kharif* season of 2017 at Agronomy farm, College of Agriculture, Nagpur to assess the effect of nutrient fortification and spacing on growth and yield of *Bt* cotton under protective irrigation. Four nutrient levels and three spacing's were tested in split plot design with 3 replications and there were twelve treatment combinations. Study revealed that, growth parameters i.e., plant height and number of sympodial branches plant^{-1} recorded highest with fortified nutrient level N_4-125% RDF with fortified Humic Acid. Similarly yield attributes i.e., Number of picked bolls plant^{-1} and seed cotton yield plant^{-1} recorded significantly highest with nutrient level N_4. Growth parameters i.e., plant height was recorded highest with plant spacing of S_1-90 cm x 45 cm. But number of sympodial branches plant^{-1} number of picked bolls plant^{-1}, seed cotton yield plant^{-1} was highest with plant spacing of S_3-120cm x 45cm. Higher seed cotton yield kg ha^{-1} was recorded with the treatment combination of 125% RDF fortified with humic acid under spacing of 90cm x 45cm (N_4S_1). But, it was remain at par with the treatment combination of 100% RDF fortified with humic acid under spacing of 90cm x 45cm (N_1S_1).

Keywords: Cotton, nutrient, spacing, humic, acid, growth, yield

Introduction
Cotton is the king of fiber crops due to its industrial importance, though it is known as "White Gold". India annually cultivates more than 11 M ha area ranks first in the world. Around 6 to 6.5 million farmers grow the crop in about 10 states of India and 60 million people are estimated to depend on it one way or the other to make out their living. Since, the release of *Bt* cotton technology, it has emerged as an effective alternative to traditional cotton varieties by inhibiting bollworm attack, thereby improving yield and income. This has resulted in fast adoption of *Bt* cotton over conventional cotton. Introduction of *Bt* cotton has played a vital role in enhancing cotton production in India. Response of cotton to applied nutrients is governed by environment and cultural factors. It is therefore necessary to study the interacting influence of fertilizer dose with spacing in cotton. Among the agronomical factors, plant spacing is an important factor which influences the growth, fruiting and yield of cotton. Plant population lower than the optimum level is one of the major reasons of low yield of cotton in India. Too high plant stand may cause adverse effect on crop yield through inter-plant competition for nutrients, light and moisture. While low plant population may not take full advantage of applied nutrients and moisture which subsequently reflects in low production. Thus, optimum plant population along with proper nutrient management is the basic factor for obtaining higher crop yield. The information on suitable plant density and fertilization is very useful for exploiting its full potentiality to boost up the yield level under protective irrigation. Keeping in mind the struggle between plants for getting more plant nutrients and moisture, it will be essential to find out the appropriate combination between spacing and fertilizer dose to achieve the maximum yield under protective irrigation. There is a need to standardize the plant spacing and fortified nutrient dose for seed production and higher yield quality seed could be achieved. A research framework was made with the purpose to assess the response of *Bt* cotton to nutrient fortification and spacing under protective irrigation and its effect on growth and yield on cotton.

Material and Methods

The field experiment was conducted during *Kharif* season of 2017 at Agronomy farm, College of Agriculture, Nagpur. The soil of experimental field was medium black. During *Kharif* 2017, the monsoon commenced from 3rd June (22MW) and was continued up to third week of September and again persists in 2nd and 4th week of October. Total rainfall *w.e.f.* June 2017 to march 2018 was 951.4 mm. Dibbling of *Bt* cotton variety Ajit-155 *Bt* BG-II was done on 3rd July, 2017. Temperature during *Kharif* ranged between 27.7^{0}C to 33.9^{0}C (Max.) and 9.9^{0}C to 23.9^{0}C (Min.) and was favorable to crop growth and germination. Average humidity was 71% (at morning) and 47% (at evening). In the present investigation four nutrient levels and three spacing's were tested in split plot design with three replications and there were twelve treatment combinations. The treatments were allotted randomly at various plots. Appropriate and timely plant protection measures were undertaken as per need to protect the crop from pests and diseases. Hoeing and hand weeding were undertaken to maintain the crop weed free, to keep the soil loose and porous for good aeration and better establishment of root system, crop growth and development. Observations on growth parameters and yield plot^{-1} were recorded and statistically analyzed with split plot design programme by adopting standard statistical technique of analysis of variance. Wherever, the results were significant, critical differences at P=0.05 level were calculated for comparison of treatment means. Data on interaction effect are presented wherever found significant.

Results and Discussion

Plant height (cm)

Fortified nutrient levels

At Harvestplant height was significantly influenced due to different levels of fortified nutrient. Maximum plant height was recorded with treatment N_4 (125% RDF with Fortified Humic Acid) which was significantly superior over treatment N_1 (100% RDF) and N_2 (75% RDF with Fortified Humic Acid). But it was at par with treatment N_3 (100% RDF with Fortified Humic Acid). Similar result were observed by Dahiphale *et al*. (2012) [3] who reported that application of nutrient level i.e. 120:60:60 NPK kg ha^{-1} was found superior for enhancing growth parameters viz., plant height, numbers of leaves, leaf area and dry matter.

Spacing

At harvest plant height was significantly influenced due to different fortified nutrient levels. Maximum plant height was recorded with spacing S_1 (90 cm x 45 cm) which was significantly superior over the spacing S_2 (90 cm x 60 cm) and S_3 (120 cm x 45 cm). It was observed that, reduction in plant height under wider plant spacing was due to suppression of apical dominance as against closer spacing which induced more vertical growth due to congestion of plant per unit area. Similar findings were recorded by Parlawar *et al*. (2017)[9] who observed that, plant spacing of 45cm x 10cm significantly more plant height than spacing of 60cm x 10cm and 60cm x 15cm.

Interaction

The interaction effects due to different treatments were found to be non-significant in respect to plant height.

No. of sympodia plant^{-1}

Fortified nutrient levels

At harvest number of sympodial branches was significantly influenced due to different fortified nutrient levels. Highest number of sympodial branches were recorded with treatment N_4 (125% RDF with Fortified Humic Acid) which was significantly superior over treatment N_2 (75% RDF with Fortified Humic Acid) and N_1 (100% RDF). But it was at par with treatment N_3 (100% RDF with Fortified Humic Acid).

Spacing

At harvest number of sympodial branches was significantly influenced due to different spacing. Spacing of S_3 (120 cm x 45 cm) recorded significantly higher number of sympodial branches plant^{-1} which was significantly superior over the spacing of S_1 (90 cm x 45 cm). But, it was at par with spacing of S_2 (90 cm x 60 cm). Similar to this results, Sisodia and Khamparia (2007) [12] and Parlawar *et al*. (2017) [9] reported decrease in number of sympodia with increased plant densities in cotton.

Interaction

Interaction effect among different fortified nutrient levels and spacing was not significant in respect to sympodial branches plant^{-1}.

No. of picked bolls plant^{-1}

Fortified nutrient levels

Different levels of fortified nutrient was significantly influenced the number of picked bolls plant^{-1}. Highest number of picked bolls plant^{-1} were recorded with treatment N_4 (125% RDF with Fortified Humic Acid) which was significantly superior over the other treatment N_1 (100% RDF) and N_2 (75% RDF with Fortified Humic Acid). However, it was at par with treatment N_3 (100% RDF with Fortified Humic Acid). The result indicated that, total number of picked bolls plant^{-1} increased with higher doses of nutrient.

Spacing

Numbers of picked bolls plant^{-1} were significantly influenced due to different spacing. Spacing of S_3 (120 cm x 45 cm) produced significantly highest total number of picked bolls plant^{-1} which is significantly superior over spacing of S_1 (90 cm x 45 cm). However, it was at par with spacing of S_2 (90cm x 60 cm). Total number of picked bolls plant^{-1} decreased in closer spacing due to lower number of sympodial branches among plants.

Interaction

Interaction effect of nutrient management and spacing (N x S) found non-significant.

Seed cotton yield plant^{-1}(g)

Fortified nutrient levels

The seed cotton yield plant^{-1} (g) significantly influenced due to different levels of fortified nutrient. Application of125% RDF with Fortified Humic Acid recorded significantly highest seed cotton yield plant^{-1}, which was significantly superior over rest of the treatments. Treatment N_2 (75% RDF with Fortified Humic Acid) produced lowest seed cotton yield plant^{-1}. Seed cotton yield plant^{-1}increases with increased level of fertilizer. Similar results were observed by Bhalerao *et al.* (2010) [1] who reported significantly higher number of bolls plant^{-1} and seed cotton yield plant^{-1} with the application of 75:37.5:00 NPK kg ha^{-1}.

Spacing

Seed cotton yield plant^{-1} was significantly influenced due to different spacing. Spacing S_3 of 120cm x 45cm recorded significantly highest seed cotton yield plant^{-1} which is significantly superior over spacing of S_1 (90 cm x 45 cm). But, it was at par with spacing of S_3 (90 cm x 60 cm). This is might be due to better aeration, adequate interception of light and lesser competition for available nutrient and moisture, which have resulted in synthesis of higher photosynthates and in turn helped to produce higher seed cotton yield plant^{-1} under wider intra row spacing. Similar results were reported by Sankaranarayanan *et al.* (2004) [11], Buttar and Singh (2007) [2] and Singh *et al.* (2016) [13] who reported plant yield increases with increase in plant spacing.

Interaction

Interaction effect significantly influences the seed cotton yield plant^{-1}. The treatment combination (N_4S_3) nutrient level of N_4 (125% RDF with Fortified Humic Acid) with spacing S_3 of 120cm x 45cm produced significantly highest seed cotton yield plant^{-1}. But, it was at par with treatment combination N_4S_2.

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

Fortified nutrient levels

Seed cotton yield kg ha^{-1} was significantly influenced due to different levels of fortified nutrients. Fortified nutrient level, 125% RDF fortified with humic acid (N_4) produced highest seed cotton yield (1960 kg ha^{-1}) which was significantly superior over rest of the nutrient levels. Further, treatments 100% RDF fortified with humic acid (N_3) (1836 kg ha^{-1}) and 100% RDF (N_1) (1834 kg ha^{-1}) were found at par with each other. However, the nutrient level 75% RDF fortified with humic acid (N_2) produced significantly lowest seed cotton yield of 1442 kg ha^{-1}. Higher seed cotton yield increase with increase in level of fortified nutrient which is the resultant effect due to higher leaf area plant-1, higher number of picked bolls plant-1 resulting in partitioning of more photosynthates towards reproductive part ultimately reflected in higher seed cotton yield. Similar findings were observed by Thokale *et al.* (2004) [14] and Jagtap and Bhale (2011) [7].

Spacing

Seed cotton yield was significantly influenced due to different spacing's. Spacing S_1 of 90cm x 45cm produced highest seed cotton yield (2133 kg ha^{-1}) which was significantly superior over rest of the spacing. However, spacing S_3 of 120cm x 45cm (1590 kg ha^{-1}) and S_2 90cm x 60cm (1581 kg ha^{-1}) produced at par seed cotton yield. The increase in seed cotton yield in closer plant spacing was due to significantly higher plant population unit^{-1} area as compared to wider spacing. Lower plant population is the major cause for its low seed cotton yield. Similar results were reported by Giri *et al.* (2008) [5], Sisodia and Khamparia (2007) [12], Bhalerao *et al.* (2010) [1], Kaur *et al.* (2010) [8], Devraj *et al.* (2011) [4] and Paslawar *et al.* (2015) [10].

Interaction

Interaction effect significantly influenced the seed cotton yield. Highest seed cotton yield was recorded under the treatment combination of 125% RDF fortified with humic acid with the spacing of 90cm x45 cm (N_4S_1) which was at par with N_3S_1 and N_1S_1 and found significantly superior over rest of the treatment combinations. Results are in the line with Hiwale *et al.* (2018) [6].

Table 1: Growth and yield of *Bt* cotton as influenced by different treatments.

Treatments		Plant height (cm)	No. of sympodia plant^{-1}	No. of picked bolls plant^{-1}	Seed cotton yield plant^{-1} (g)	Seed cotton yield kg ha^{-1}
A.	**Nutrient levels (N)**					
	N_1- 100% RDF 120:60:60 NPK kg ha^{-1}	145.67	15.48	61.19	125.05	1834
	N_2- 75% RDF fortified with humic acid	133.22	13.78	51.74	111.89	1442
	N_3- 100% RDF fortified with humic acid	149.44	16.72	64.22	127.47	1836
	N_4- 125% RDF fortified with humic acid	153.22	17.27	67.44	138.86	1960
	S.E. (m) ±	2.07	0.30	1.13	1.34	31.94
	CD at 5%	6.08	0.88	3.32	3.93	93.68
B.	**Spacing (S)**					
	S_1- 90 cm x 45 cm	150.58	14.21	56.25	119.58	2133
	S_2- 90 cm x 60 cm	144.25	16.31	62.63	128.19	1581
	S_3- 120 cm x 45 cm	141.33	16.92	64.57	129.69	1590
	S.E. (m) ±	1.80	0.26	0.98	1.16	27.66
	CD at 5%	5.27	0.77	2.87	3.41	81.13
C.	**Interaction (NxS)**					
	S.E. (m) ±	3.59	0.52	1.96	2.32	55.33
	CD at 5%	NS	NS	NS	6.81	162.26

Table 2: Seed cotton yield plant^{-1} (g) as influenced by interaction effect

N X S	Seed cotton yield plant^{-1} (g)		
	S_1	S_2	S_3
N_1	123	125	127
N_2	105	115	116
N_3	124	128	131
N_4	127	144	145
SE(m)±	2.18		
CD at 5%	7.00		

Table 3: Seed cotton yield (kg ha^{-1}) as influenced by interaction effect

N X S	Seed cotton yield ha^{-1} (kg)		
	S_1	S_2	S_3
N_1	2266	1612	1625
N_2	1662	1338	1327
N_3	2277	1601	1633
N_4	2330	1776	1776
SE(m)±	55		
CD at 5%	162		

Conclusions

Fortified nutrient level N_4 (125% RDF with fortified Humic Acid) recorded highest plant height, number of sympodia plant^{-1}, number of picked boll plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1}. Among all plant spacing, spacing of 120cm x 60cm recorded maximum number of sympodial branches plant^{-1}, number of picked boll plant^{-1} and seed cotton yield plant^{-1}. However plant spacing of 90cm x 45cm recorded higher seed cotton yield ha^{-1}.

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