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Performance of Bollgard I with different plant spacing and in presence of refuge crops

Preeti Singh, PJ George, PW Ramtweke and Anupriya Paul

Abstract
Different biotic and abiotic factors affect the growth and yield of *Bt* cotton. Appropriate agronomic practices like plant density and presence of refuge crops have profound effect on the development and final outcome of the crop. A field experiment was conducted to assess the performance of Bollgard I variety (cotton 1007-9810 BGI) of *Bt* cotton under different plant spacing (30 x 30 cm, 60 x 60 cm and 80 x 80 cm) and in presence of 50% refuge *nBt* cotton (cotton Mahesh) which is a different cultivar, at Horticulture Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad (Uttar Pradesh). It was noted that plant height was found significantly higher in closer spacing whereas monopodial branches plant^{-1} (1.73, 1.60), sympodial branches plant^{-1} (16.66, 12.33), bolls plant^{-1} (20.33, 17.44), average boll weight plant^{-1} (3.30, 3.23), seeds plant^{-1}(452.99, 411.66) and lint weight (g) plant^{-1} (17.61, 14.02) were recorded higher in 80 x 80 cm followed by 60 x 60 cm, and 30 x 30 cm. Comparison of *Bt* yield attributes with refuge n*Bt* from the field trial containing 50 % refuge n*Bt* cotton recorded maximum yield attributes in *Bt* cotton.

Keywords: Abiotic, biotic, *Bt* cotton, refuge *nBt* cotton, spacing

Introduction
Cotton is a natural part of everyday life which serves the mankind from birth to death. It is a major agricrop or cash crop playing a key role in economic and social affairs of the world (Kairon *et al.*, 2004) [1]. The cotton fibers which is an important part, used to make breathable to various textile industries. It is also known as “king of fibers” or “white gold” because of its higher economical value and its prominent role in farming among all cash crops in India. The various biotic and abiotic factors affect the growth, development and yield of *Bt* cotton (Pearce and Fred, 2004) [2]. Cultivation of *Bt* cotton is used to alleviate the effect of agricultural intensification and produces more yields (Cattaneo *et al.*, 2006) [3].

Cotton crop plays a special role in Indian economy. India is the only country in the world which grows all four types of cultivated species of cotton (Nagendra *et al.*, 2017) [4]. By introducing new phase of cotton in the country, has helped to solve various insects pest problems. It provides resistance to pests and therefore its cultivation not only reduces the use of chemical pesticides but increases the yields (Huang *et al.*, 2010) [5].

Among all agronomical factors, plant geometry is an important factor which influences the growth, fruiting and yield of *Bt* cotton. Plant population lower than the optimum level is one of the major reasons for low yield of *Bt* cotton. To high plant density may causes adverse effect on crop yield due to more inter plant competition for nutrients and moisture (Prasad and Prasad, 1993) [6]. Maximum yield can be obtained by maintaining optimum plant population according to plant morphological characteristics (Ali *et al.*, 2009) [7]. The pervasive and intensive use of different mock insecticides to control various pests caused adverse effect on the environment and create ecological imbalance due to excessive persistence of residues, harmful effect on non-target organisms (Dahi *et al.*, 2012) [8]. Strong need of *Bt* cotton, allows resistance to bollworms. To delay and manage resistance in the field environment, frequent solutions are adopted and apply Insect resistance management strategies by cultivating *Bt* plants with refuge of *nBt* plants. Field trials conducted at various regions in India have indicated better yield potential of *Bt* cotton as compared to non *Bt* hybrids (Gould *et al.*, 1998) [9].

During our investigation the growth and yield parameters in Bollgard I variety of *Bt* cotton in different spacing and presence of 50% *Bt* with 50% refuge *nBt* cotton were studied, found significantly higher in wider spacing and 50% *Bt* cotton.

Materials and Methods

Experimental location and meteorological information: A field experiment was carried out at Horticulture Research Farm of the Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh in mid-March during the summer season of 2014 and 2015 to study the effect of spacing and refuge crops on growth and yield of *Bt* cotton (*Gossypium hirsutum)* hybrids. The experimental site located at 20° 15’42’’ North latitude and 60° 50’31’’ East longitude and 98 m altitude above the main sea level. The climatic conditions of Allahabad area comes under subtropical belt of South East of Uttar Pradesh which experiences extremely hot summer and fairly cold winter. The rainfall was not very low in this region but erratic in nature throughout crop season particularly during boll formation to first boll opening which considerably reduced the final yield. The average rainfall in this area is about 882 mm. The soil of experimental plot was sandy loam soil containing uniform with low amount of clay (30.52) and high percent of sand (48.16) with low in organic carbon (0.44%) and available K_2O (210.54 kg/ha), medium in P_2O_5 (37.33 kg/ha) and high in N (212.54 kg/ha). The pH and EC (ds/m) of experimental soil was 6.87 and 0.14, respectively.

Experimental design: Experiment was conducted in a completely randomized design with two plots by making furrows for each treatment. Two plots were maintained, one small plot (3.0 x 3.0 m^2) and other is big plot (6.0 x 6.0 m^2). Small plots containing five rows and five columns whereas big plot containing 10 rows and 10 columns. Small plot have two spacing treatment, 30 x 30 cm and 80 x 80 cm spacing and for big plot 60 x 60 cm spacing in which 50% *Bt* with 50% refuge *nBt* cotton.

Materials and cultivation operations: The seeds of *Bt* cotton ‘1007-9810, BG I variety’ and non *Bt* cotton ‘Mahesh variety’ was obtained from Dr. G Garg, Krisidhan Jalna Maharashtra. The selected field was harrowed and ploughed with a cultivar before sowing and later the soil was turned to a fine tilth. Before sowing Farm yard manure 1.25 kg/m^2, Phosphorus was applied in the form of DAP at 8.7g/m^2, urea as source of nitrogen at 14g/m^2, and MOP as a source of potassium, at 6.6 g/m^2 were applied in the field. No pesticides were used during the small scale field trial. Entire manure was applied at the time of sowing. Irrigation was done at 15-20 days intervals during the experiment. Hand weeding was followed to remove the weeds and bolls were harvested in six picking. All other cultural operations were adopted throughout the growing period uniformly in all treatments.

Data collection and analysis: For recording agronomic characters, three plants were selected randomly from each treatment and observations were recorded for plant height (cm), monopodial branches plant^{-1}, sympodial branches plant^{-1}, total bolls plant^{-1}, average boll weight (g), seeds plant^{-1}, and weight of lint (g) plant^{-1}. All the collected data were statistically subjected to one-way ANOVA test and bar charts made by using Microsoft Excel Program 2010 and ± standard error (S.E.) was used to test the significance. All statistical analysis was performed by using Wasp software package (Steel *et al.*, 1997) [10].

Results and Discussion

Growth and yield parameters

Plant height (cm): Plant height of *Bt* cotton (BG I) was recorded significantly higher with 30 x 30 cm S_1: (114.44, 99.33), followed by 60 x 60 cm S_2: (106.88, 93.34) and less plant height displayed in 80 x 80 cm S_3: (95.55, 82.88) during 2014 and 2015 respectively (Table 1). These results are similarly reported by Narayana *et al.*, (2007) [11] and Siddiqui *et al*., (2007) [12]. However Anjum *et al.*, (2003) [13] found that no effect of spacing on plant height. Morphological changes in plants are stimulated when plant density is increased because more competition between plants to plants for light when soil fertility and moisture are not limited. Increased plant density results mutual shading of plants which generally results in stem elongation. For individual plant horizontal space at closer spacing is decreased, due to which intense inter plant competition for nutrient and light suppressed and plant grew more in vertical space (Wang *et al.*, 2011) [14]. It was noted that 50% refuge *nBt* cotton (110.00, 107.55) attain maximum height in comparison to 50% *Bt* cotton (99.66, 91.11). These variations in plant height were due to different cultivar, environmental factor and nutritional stress (Manjunatha *et al.*, 2010; Singh *et al.*, 2015) [15].

Monopodial branches plant^{-1}: The statistical analysis of data showed in Table 1. indicated that there was significant effect between treatments. It was observed that monopodial branches plant^{-1} at spacing 80 x 80 cm gave more number branches (1.73, 1.60) which was significantly superior to S_2: 60 x 60 cm (1.61, 1.50) and S_1: 30 x 30 cm (1.20, 1.10) during both years respectively. These results are in accordance with Reddy and Gopinath (2008) [16] found that wider plant spacing allows to achieve more number of branches due to more efficiency in the rate of photosynthesis. It was further showed that 50% *Bt* cotton gave significantly higher number of monopodial branches plant^{-1} (2.00, 1.77) than 50% refuge *nBt* cotton (1.20, 1.10). The possible reason of this might be due to differences found in genetic makeup of different cultivars, environmental and nutritional stress (Aruna *et al.*, 2016) [17].

Sympodial branches plant^{-1}: More number of sympodial branches plant^{-1} is an indication of good yield in *Bt* cotton. Sympodial branches plant^{-1} was significantly affected by various spacing treatments and presence of refuge crops. During both years of investigation, significantly more number of sympodial branches plant^{-1} were observed when crop was sown with 80 x 80 cm (16.66, 12.33) which was significantly superior to 60 x 60 cm (12.44, 10.55) and lesser number was recorded in 30 x 30 cm (5.22, 4.66) respectively. The increase in number of sympodial branches plant^{-1} might be due to more availability of space and less competition between plants to plants. These observations are same with the findings of Hussian and Qasim (2003) [18] while in case of refuge crops 50 % *Bt* achieved significantly more number of sympodial branches plant^{-1} (14.66, 12.88) than the 50 % *nBt* refuge cotton (9.32, 7.87). Branching is genetically governed factor until and unless there are abrupt changes in the environment affects the branching of two different cultivars (Nagender *et al.*, 2017) [19].

Bolls plant^{-1}: Number of bolls plant^{-1} is an important yield contributing parameters. Results presented in Table 2. indicated that by increasing plant spacing there was significant increase in number of bolls plant^{-1}. In 2014 and 2015, significantly more number of bolls plant^{-1} (20.33, 17.44) was observed in S_3: 80 x 80 cm which was statistically significant over S_2: 60 x 60 cm (16.66, 14.66) and least number were counted in S_1: 30 x 30 cm (11.10, 9.11) spacing treatment respectively. Likewise cotton sown with 80 x 80 cm spaced plants gave maximum number of bolls per plant among all spacing treatments while cotton sown with 30 x 30 cm showed minimum number of bolls per plant during 2014 and 2015. Increase in number of bolls plant^{-1} with increased spacing can be attributed due to more availability of space, less competition and more number of sympodial branches per plant. These results are accordance with the results reported by Siddiqui *et al.,* (2007) [12] who stated that increase in density decrease the number of bolls per plant.

50% *Bt* gave significantly higher number of bolls when compared to 50 % *nBt* refuge cotton. Significantly more number of bolls plant^{-1} was attained by 50% *Bt* (18.77, 15.66) and least were recorded in 50% refuge *nBt* cotton (10.44, 9.10) respectively (Table 1). Likewise 50% *Bt* cotton resulted more number of bolls than the 50% *nBt* cotton during 2014 and 2015. The probable reason of this might be due to fewer bolls damaged in case of *Bt* cotton by the bollworms or other insects, this was due to presence of Cry1Ac gene in *Bt* cotton and bearing greater number of sympodial branches also affects the number of bolls plant^{-1} (Sankaranarayanan *et al.*, 2011; Aruna *et al.*, 2016) [19, 17].

Table 1: Plant height (cm), monopodial branches plant^{-1} and sympodial branches plant^{-1} in Bollgard I variety of cotton as influenced by plant spacing (S_1, S_2, & S_3) and cultivar (V_1 & V_2) during 2014 and 2015.

Treatment	Plant height at harvest (cm)		No. of monopodial branches plant^{-1}		No. of sympodial branches plant^{-1}	
Spacing	**2014(Y_1)**	**2015(Y_2)**	**2014(Y_1)**	**2015(Y_2)**	**2014(Y_1)**	**2015(Y_2)**
S_1: 30 x 30 cm	114.44	99.33	1.20	1.10	5.22	4.66
S_2: 60 x 60 cm	106.88	93.34	1.61	1.50	12.44	10.55
S_3: 80 x 80 cm	95.55	82.88	1.73	1.60	16.66	12.33
Mean	105.62	91.84	1.51	1.40	11.44	9.18
SEm±	1.23	1.12	0.16	0.14	1.64	0.77
CD(P=0.05)	2.45	2.25	0.33	0.28	3.29	1.55
CV%	1.16	1.22	11.02	10.10	14.41	8.45
Cultivar						
V_1: 50% *Bt* cotton	99.66	91.11	2.00	1.77	14.66	12.88
V_2: 50% refuge *nBt* cotton	110.00	107.55	1.20	1.10	9.32	7.87
Mean	104.83	99.33	1.60	1.43	11.99	10.37
SEm±	0.94	0.77	0.12	0.18	0.62	0.56
CD(P=0.05)	2.13	1.74	0.27	0.42	1.41	1.27
CV%	1.89	1.77	7.65	12.88	5.19	5.40

Average weight (g) of bolls plant^{-1}: Boll weight is another important yield contributing parameters for cotton. Data given in Table 2. indicated that average boll weight (g) influenced by various plant spacing and in presence of refuge crops. During 2014 and 2015, more boll weight (g) plant^{-1} was recorded in wider spacing i.e., 80 x 80 cm (3.30, 3.23) followed by 60 x 60 cm (3.16, 3.12) and least value was obtained in 30 x 30 cm (3.09, 3.04) spacing. Boquet (2005) [20] stated that greater average boll weight at more plant spacing might be due to more availability of resources and less struggle between plants to plants.

Results pertaining in Table 2. showed that heavier boll weight (g) plant^{-1} was found in 50% *Bt* (3.31, 3.27) against the 50% *nBt* (2.99, 2.92) refuge cotton. The superior performance of *Bt* hybrid might be due to inbuilt resistance against bollworms by the presence of *Bt* gene (Aruna *et al.,* 2016; Nagender *et al.,* 2017) [17, 4].

Seeds plant^{-1}: Significantly higher number of seeds plant^{-1} was obtained in S_3: 80 x 80 cm (452.99, 411.66) followed by S_2: 60 x 60 cm (358.44, 328.10) and least number was counted when crop is sown at S_1: 30 x 30 cm (254.22, 242.33) spacing (Table. 2). During both years of investigation, higher seed index was found in wider spacing i.e., S_3 treatment (8.32, 8.06) and lower seed index was recorded $S_{1:}$ (7.32, 7.22) treatment respectively. Number of seeds plant^{-1} was affected by number of bolls and average boll weight of the plant, this decrease in yield might be due to over population and more competition between plants for light and nutrients. Boquet (2005) [20] found that by increasing plant density, boll weight and number of bolls plant^{-1} decreases ultimately reduces the final yield.

The comparison between 50% *Bt* gave significantly maximum number of seeds plant^{-1} (393.33, 357.66) against the 50% refuge *nBt* cotton (207.88, 196.55) during both year of investigation. Seed index plant^{-1} was recorded higher in in 50% *Bt* (8.20, 7.96) when compared to 50% refuge *nBt* cotton (7.30 7.12) respectively. Highest number of seeds and seed cotton yield was evidently affected by number of bolls per plant and boll weight of *Bt* hybrids than *nBt* cotton. Similarly Khadi *et al.,* (2008) [21], who found highest number of seeds plant^{-1} in 90 % *Bt* with 10 % refuge *nBt* cotton whereas Nagendra *et al.*, (2017) [19] observed that highest seed cotton yield in *Bt* hybrids than *nBt* cultivar.

Lint weight (g) plant^{-1}: Lint is another important character regarding for yield components and used as raw material for various textile industries. Plant spacing showed significant outcome on weight of lint (g) plant^{-1} (Table 2). Results showed that highest lint weight (g) plant^{-1} was found in S_3: 80 x 80 cm (17.61, 14.02) which was significantly over than S_2: 60 x 60 cm (13.33, 11.05) whereas S_1: 30 x 30 cm (8.40, 7.89) exhibited lower lint weight (g) plant^{-1} during both years of experiment respectively. It is a result of number of bolls plant^{-1}, average boll weight and good bolls plant^{-1} also affects the weight of lint. These results in accordance with Siddiqui *et al.,* (2007) [12], who found highest lint weight (g) plant^{-1} in 35 to 25 cm apart whereas lowest, were found in 15 cm spacing.

In 2014 and 2015, significantly more lint weight per plant was obtained in 50% *Bt* (14.77, 13.12) in comparison to 50% *nBt* (5.95, 5.45) refuge cotton. This difference may be due to different cultivars, more number of bolls plant^{-1}, heavier boll weight (g) plant^{-1}, and less damaged by bollworms due to presence of Cry1Ac gene in *Bt* cotton directly affects the weight of lint (g) plant^{-1}.

Results indicated that all growth and yield parameters are found higher in wider spacing than other spacing treatments except plant height (cm). The entire yield contributing characters was found positively correlated with number of monopodial and sympodial branches of cotton plants. No pesticides were applied during both trials this might be due to presence of *Bt* crops which is sufficient to protect 50% *nBt* refuge cotton plants when sown alternatively with 50% *Bt* cotton. *Bt* cotton performed better than the non *Bt* cultivar. The refuge *nBt* cotton produced less negative impact than any chemical control and helps to development resistance in *Bt* cotton.

Table 2: Number of bolls plant^{-1}, average weight of Bolls (g) plant^{-1}, number of seeds plant^{-1}, and weight of lint (g) plant^{-1} in Bollgard I variety of cotton as influenced by plant spacing (S_1, S_2 & S_3) and cultivar (V_1 & V_2) during 2014 and 2015.

Treatment	No. of bolls plant^{-1}		Average weight of bolls (g) plant^{-1}		No. of Seeds plant^{-1}		Weight of lint (g) Plant^{-1}	
Spacing	2014 (Y_1)	2015(Y_2)	2014(Y_1)	2015(Y_2)	2014(Y_1)	2015(Y_2)	2014(Y_1)	2015(Y_2)
S_1 : 30 x 30 cm	11.10	9.11	3.09	3.04	254.22	242.33	8.40	7.89
S_2 : 60 x 60 cm	16.66	14.66	3.16	3.12	358.44	328.10	13.33	11.05
S_3 : 80 x 80 cm	20.33	17.44	3.30	3.23	452.99	411.66	17.61	14.02
Mean	16.03	13.73	3.18	3.13	355.22	327.36	13.11	10.98
SEm±	0.40	0.45	0.03	0.04	3.23	5.18	0.56	0.71
CD(P=0.05)	0.79	0.91	0.05	0.08	6.46	10.36	1.13	1.42
CV%	2.49	3.34	0.91	1.31	0.91	1.58	4.32	6.50
Cultivar								
V_1: 50% *Bt* cotton	18.77	15.66	3.31	3.27	393.33	357.66	14.77	13.12
V_2: 50% refuge *nBt* cotton	10.44	9.10	2.99	2.92	207.88	196.55	5.95	5.45
Mean	14.60	12.38	3.14	3.09	360.60	277.10	10.36	9.28
SEm±	0.83	0.59	0.07	0.06	3.81	1.55	0.57	0.40
CD(P=0.05)	1.90	1.34	0.15	0.15	8.63	3.51	1.31	0.91
CV%	5.73	4.77	2.13	2.14	1.26	0.56	5.59	4.32

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