Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 477-479
Received: 10-07-2018
Accepted: 12-08-2018

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Effect of number of plants per hill in respect to plant geometry in Bt cotton (*Gossypium hirsutum* L.) under rainfed condition

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Abstract
An experiment was conducted at Cotton Research Station, Nanded during three cropping seasons (2012-15) to evaluate effect of one plant hill^{-1} under different plant geometries in comparison with two plants hill^{-1} under rainfed condition. The treatments were factorial combinations of three plant geometries (90 x 60 cm, 120 x 45 cm and 150 x 30 cm) and number of plants hill^{-1} (one and two plants hill^{-1}). There was 12.08 per cent increase in seed cotton yield when Bt cotton was planted in 120 x 45 cm geometry over that of 150 x 30 cm. Similarly increase in bolls plant^{-1}, boll weight, yield plant^{-1} and monetary returns were also received from 120 x 45 cm geometry over wider. The one and two plants per hill^{-1} had non-significant results for seed cotton yield, yield attributes although number of branches were more in two plants hill^{-1}. The Moisture content in soil at 60 DAS and ginning out turn were not affected significantly due to plant geometries and number of plants hill^{-1}.

Keywords: Effect, number, plants per hill, respect, plant geometry, Bt cotton

Introduction
Cotton (Gossypium spp.) is an important fibre crop of India. It contributes to 85 per cent of total raw material of textile industries. Cotton plays a key role in the national economy in terms of exchange earnings. India has unique distinction of cultivating cotton in 122.35 lakh ha. India ranks first in area and second in production in the world although have low productivity. The productivity of Maharashtra state is 344 kg/ha which is very much lower than national productivity (523 kg/ha). In Maharashtra, Bt cotton is being under cultivation since year 2002, and it had made breakthrough in cotton production of the state. Bollworm alone takes a heavy toll costing the farmers an annual loss more than one third of current insecticides use in India. By incorporation of insect tolerance by means of *Bt* gene, the yield loss by means of lepidopterous insects was minimized. As production levels were increased, it is necessary to change the production technology to get maximum benefit of the transgenic crop. Establishment of optimum plant population of cotton seedling is paramount to obtain higher yields in cotton. Hence optimum plant population and fertilizer levels as per the region and soil conditions were standardized. Planting density of 18,518 plants ha^{-1} for rainfed condition was found optimum for black cotton soils in Marathwada region (Khargkharate *et al.*, 2008) [4]. The plant geometry of 120 x 45 cm was found suitable and was recommended for vertisols in the region under rainfed condition (Pandagale *et al.*, 2015) [7]. However, cotton crop is maintained with two plants per hill since non transgenic time under rainfed condition (Anonymous, 2006) [1]. Hence there will more demand for space and nutrition for two plants sown and maintained per hill. The higher cost of Bt cotton seed also plays a key role in economy of resources poor farmers in Maharashtra. It always necessary to minimize cost of cultivation to increase profitability in dryland farming. Curtailing cost of seed can help to improve the net benefit of farmers. Hence, the present investigation was under taken to study the effect of keeping one plant of Bt cotton hybrid hill^{-1} under varied plant geometry in comparison with two plants under rainfed condition.

Materials and methods
A field experiment was conducted at Cotton Research Station, Nanded (M.S., India) to evaluate response of number of plants per hill with respect of different plant geometry in Bt cotton. The field trial was conducted during 2012-13 to 2014-15 for three years with two factors *viz.*, number of plants hill^{-1} (one and two plants hill^{-1}) and plant geometries (90 x 60 cm; 120 x 45 cm and 150 x 30 cm). The six treatment combinations were studied with four replications and were analyzed in FRBD design. The soil of experimental field was neutral in pH, low in available N (105.41 Kg ha^{-1}), medium in available phosphorus (8.39 Kg ha^{-1}) and

high available potash content (466.18 Kg ha^{-1}). The Bt cotton hybrid 'Bunny' was sown after receipt of sufficient monsoon rains and the research trial was conducted under rainfed condition. Sowing was done with three plant geometries, 90 x 60 cm (18,518 plants ha^{-1}), 120 x 45 cm (18,518 plants ha^{-1}) and 150 x 30 cm (22,222 plants ha^{-1}). Two and three seeds were sown per dibble at the time of sowing and thinning was done at 10 days after sowing to maintain one and two plants per hill, respectively.

Observations on plant growth, yield attributes and yield from five labeled plants per treatment plots were recorded and mean values were considered for analysis. Moisture content in soil at boll development stage (120 DAS) was measured at 30 cm depth. As all the interaction effects were found non-significant for all the parameters, mean values of each individual factors are presented in tables and used for discussion after pooled analysis.

Results and discussion

Plant growth characters and yield attributes

The differences in plant growth characters were not evident with respect to plant geometries (Table 1). However, the geometries 90 x 60 cm and 120 x 45 cm were found to have significantly larger boll size (3.23 g and 3.22 g, respectively) than geometry 150 x 30 cm (3.06 g). Similarly, geometry 120 x 45 cm recorded highest number of bolls hill^{-1} (32.88) which were significantly more than geometry 150 x 30 cm (24.41). Significant increase in bolls hill^{-1} and boll weight resulted to increase in yield hill^{-1} in 120 x 45 cm (105.28 g) and 90 x 60 cm (103.42 g). Phogat *et al.*, (2010) [8] revealed that less number of bolls and yield hill^{-1} in closest intra row spacing might be due to reduced availability of resources for development of reproductive parts.

Significant increase in number of monopodial and sympodial branches hill^{-1} in two plants hill^{-1} as compared to one plant hill^{-1} were recorded. The boll weight in one plant hill^{-1} (3.23 g) was found to increased statistically over that of two plants hill^{-1} (3.11 g). This might be due to less competition in one plant hill^{-1} for nutrients and moisture than that of two plants. However, increase in branches didn't influenced number of bolls hill^{-1} resulting non-significant differences in one and two plants per hill for yield hill^{-1}. Interactions between plant geometry and number of plants hill^{-1} for plant growth characters, yield attributes and seed cotton yield ha^{-1} were not significant.

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

During year first and third year of experimentation, the plant geometry had significant impact on seed cotton yield (kg ha^{-1}). The geometries 90 x 60 cm and 120 x 45 cm (both with density 18,518 plants ha^{-1}) were significantly superior over 150 x 30 cm (density 22,222 plants ha^{-1}) for seed cotton yield ha^{-1}, yield and bolls hill^{-1}. On pooled analysis, geometry 120 x 45 cm recorded highest seed cotton yield (1913 kg ha^{-1}) and was at par with 90 x 60 cm geometry (1853 kg ha^{-1}). The seed cotton yield in wider row spacing of 150 x 30 cm was found to be significantly reduced. This was due to lower number of bolls hill^{-1} and boll weight. Khargkharate *et al.*, (2008) [4] revealed that density 18,518 plants ha^{-1} (geometry 90 x 60 cm) is optimum than density 24,691 plants ha^{-1} (geometry 90 x 45 cm) and 12,341 plants ha^{-1}(90 x 90 cm geometry) for Bt cotton in Marathwada condition under rainfed condition. Kulvir *et al.*, (2007) [5] also reported higher seed cotton yield of Bt cotton hybrids under 67.5 x 90 cm spacing than 90 x 75 cm and 90 x 90 cm.

Statistical differences were not observed for seed cotton yield ha^{-1} due to one or two plants hill^{-1} during all the years of experimentation and on pooled mean basis. However, there was 5.84 per cent increase in seed cotton yield in two plants hill^{-1} over that of one plant. This increase may be due to enlargement in boll weight in single plant over two plants hill^{-1}. But significant differences were not observed as there were no increase in number of bolls hill^{-1} and yield hill^{-1}. Hawkins *et al.*, (1971) [3] also reported that there were non-significant differences in yield when 2, 3, 4 and 5 plants of cotton were planted hill^{-1}. Tug well and Waddle (1964) [9] observed no significant differences in yield in three years study comparing one plant hill^{-1} with three to five plants^{-1}. Work by Ogunela and Odion (2006) [6] revealed that two plants hill^{-1} had increased plant height which is in confirmation with the present study. There was increase in number of branches and boll size in two plants over one plant hill^{-1}.

Interaction effect of Geometry x Plants per hill: The interaction of plant geometry x number of plants hill^{-1} were found non-significant during all years of experimentation and on pooled analysis.

Ginning out turn

The ginning outturn was not statistically differed due to plant geometry and number of plants hill^{-1} (Table 2). Similar results for plant geometry were reported during 2008-10 by Pandagale *et al* (2015) [7].

Moisture content

The moisture content at 30 cm depth was not affected significantly at 120 DAS (boll development stage). However, the plant geometry of 90 X 60 cm and 120 X 45 cm had higher numerical values (Table 2). The increase in moisture by 19.83 and 17.19 per cent, respectively in plant geometry of 90 X 60 cm and 120 X 45 cm was over 150 x 30 cm. Hake *et al.*, (1991) [2] revealed that more use of water by greater number of plants per unit area than thin stands because of greater root exploration of moist soil and more total leaf area that requires more water. Cotton usually suffers drought in mid to late season when low density may have little benefit because plants have compensated with increased rooting leading to greater utilization of moisture in low stand as much as a high stand.

Economics

Income and profitability was found to differ due to plant geometry (Table 2). Highest mean gross and net monetary returns were recorded from plant geometry 120 x 45 cm (Rs. 86,888/- ha^{-1} and Rs. 42,319/- ha^{-1}, respectively). The geometry of 90 x 60 cm was found on par with geometry 120 x 45 cm for GMR and NMR. The wider row spacing (150 x 30 cm) was found to reduce monetary returns significantly. Similarly, the maximum B:C ratio was also received in plant geometry of 120 x 45 cm (1.90). This was due to higher yields under 120 x 45 cm geometry without additional cost of cultivation over 150 x 30 cm. This is in confirmation with Pandagale *et al* (2015) [7] under similar situations.

Gross and net monetary returns from keeping one plant hill^{-1} (Rs. 80,436 ha^{-1} and Rs. 37,846/- ha^{-1}, respectively) were statistically on par with two plants hill^{-1} (Rs. 85,075 ha^{-1} and Rs. 38,893/- ha^{-1}, respectively) on pooled mean basis. This clearly suggests that there will not be increase in net profit by keeping a single plant hill^{-1} instead of two plants as it is kept conventionally. Expenditure on seed was doubled in two plant

hill^{-1} without significant increase in seed cotton yield might have lowered monetary returns keeping it comparable with single plant. However, a net monetary return was higher by Rs. 1047/- per ha^{-1} by keeping two plants hill^{-1} over keeping single plant.

The interaction of plant geometry x number of plants hill^{-1} were found non-significant for GMR and NMR during all years and on pooled basis.

Conclusion

Based on the results of three years study it can be concluded that plant geometry of 120 x 45 cm is suitable for Bt cotton in deep black soils under rainfed condition. Maintaining two plants of Bt cotton hill^{-1} gives comparable seed cotton yield as well as monetary returns over one plant hill^{-1}.

Table 1: Plant growth, yield contributing characters and Seed cotton yield as influenced by plant geometry and number of plants hill^{-1}

Treatment	Plant height (cm)	Mono-podia plant^{-1}	Symp-odia plant^{-1}	Yield plant^{-1} (g)	No. of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})			
							2012-13	2013-14	2014-15	Pooled mean
Plant geometry										
G_1: 90 x 60 cm	108.27	1.54	17.70	103.42	29.38	3.23	1355	2611	1593	1853
G_2: 120 x 45 cm	111.98	1.61	18.09	105.28	32.88	3.22	1412	2754	1574	1913
G_3: 150 x 30 cm	113.63	1.51	19.14	79.47	24.41	3.06	1099	2672	1273	1682
SE±	1.69	0.04	0.40	2.71	1.33	0.04	50.33	116.95	70.38	45.36
CD at 5%	N.S.	N.S.	N.S.	8.53	4.18	0.11	151.43	N.S.	211.78	142.71
No. of plants hill^{-1}										
P_1: One plant hill^{-1}	110.26	1.39	16.50	91.21	28.28	3.23	1241	2578	1474	1764
P_2: Two plants hill^{-1}	112.33	1.72	20.12	100.90	29.51	3.11	1336	2780	1486	1867
SE±	1.38	0.03	0.30	2.61	1.08	0.03	41.10	67.52	57.46	37.04
CD at 5%	N.S.	0.10	1.09	N.S.	N.S.	0.09	N.S.	N.S.	N.S.	N.S.
Interaction G x P										
SE±	2.39	0.06	0.60	3.83	1.88	0.05	71.17	116.95	99.53	64.15
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
GM	111.29	1.55	18.31	96.05	28.89	3.17	1289	2679	1480	1816

Table 2: GOT, moisture content and economics as influenced by plant geometry and number of plants hill^{-1}

Treatment	Ginning out turn (%)	Moisture content at 120 DAS (%)	GMR (Rs. ha^{-1})	NMR (Rs. ha^{-1})	B:C ratio
Plant geometry					
G_1: 90 x 60 cm	34.63	14.50	84363	39739	1.85
G_2: 120 x 45 cm	34.62	14.18	86888	42319	1.90
G_3: 150 x 30 cm	34.63	12.10	77015	33051	1.67
SE±	0.21	0.83	1905	1708	0.03
CD at 5%	N.S.	N.S.	5992	5373	0.10
No. of plants / hill					
P_1: One plant hill^{-1}	34.60	14.33	80436	37846	1.84
P_2: Two plants hill^{-1}	34.65	12.85	85075	38893	1.78
SE±	0.17	0.68	1555	1395	0.03
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction G x P					
SE±	0.31	1.17	2694	2415	0.04
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.
GM	34.62	13.59	82755	38370	1.81

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