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Physiological Characters and Seed Cotton Yield of Bt Cotton (*interspecific*) as Influenced by Crop Geometry and Drip Fertigation

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Field experiments were conducted during 2012-2013 and 2013-14 at Tamil Nadu Agricultural University, Coimbatore to study the physiological characters of Bt cotton as influenced by crop geometry and drip fertigation. The experiment was laid out in a strip plot design with replicated thrice. The treatments in main plot consisted of four crop geometry levels (120 x 60 cm, 120 x 90 cm, 150 x 60 cm and 150 x 90 cm) and sub plots consisted of four nutrient levels *viz.,* 75, 100 and 125 % of recommended dose as water soluble fertilizer (WSF) through drip system and conventional practice of irrigation and fertilizer application. Here, 75 % of the P as basal (single super phosphate) and remaining 25 % P as water soluble fertilizer and the entire quantity of N and K as water soluble fertilizer was applied based on recommended fertigation schedule. The experimental results revealed that crop growth rate was significantly higher under 120 x 60 cm and was comparable with crop geometry of 120 x 90 cm with application of 125 % of recommended dose as water soluble fertilizer over wider crop geometry level of 150 x 90 cm compared to conventional method of irrigation and fertilizer application. Higher seed cotton yield was recorded with crop geometry of 120 x 90 cm with 125 % as water soluble fertilizer over conventional method of cultivation.

Key words: Crop geometry, Fertigation, Physiological characters, Seed cotton yield.

Cotton is the world's leading fibre crop and second most important oil seed crop. Bt cotton, on commercial scale was started in 2002 in India and it is occupying around 80 per cent out of 9.1 m ha with an increased production of 310 lakh bales (AICCIP, 2012). The incorporation of *Bacillus thuriengensis* bacteria in cotton has changed the crop morphology, phenology, physiology and translocation efficiency of photosynthate into bolls (Chen *et al.,*2002). Among the improved agronomic practices, important yield contributing agrotechniques are crop geometry and fertilizer application. Increased and efficient use of nutrients is one of the options for increasing cotton productivity. Drip irrigation and use of water soluble fertilizers (WSF) by drip fertigation is found to increase the efficiency in the application of fertilizer and water besides reducing the quantity of fertilizer applied. Since there is good interaction between crop geometry and applied fertilizer, especially under drip fertigation, opportunities exits for enhancing the productivity of Bt cotton. Physiological characters *viz.,* crop growth rate, specific leaf area and chlorophyll content of the crop plays a major role to enhancing the crop productivity. Taking this aspect into consideration, a field investigation was carried out to study the physiological characters of Bt cotton as influenced by different crop geometry and levels drip fertigation.

Materials and Methods

A field experiment was carried out during 2012 - 13 and 2013-14 at Tamil Nadu Agricultural University, Coimbatore to study the physiological characters of Bt cotton as influenced by different crop geometry and levels of drip fertigation through drip irrigation system. The experiment was laid out in a strip plot design with three replications. The main plot treatments consisted of four crop geometry levels *viz.,* M_1 - 120 x 60 cm, M_2 - 120 x 90, M_3 - 150 x 60 cm and M_4 - 150 x 90 cm. The sub plots consisted of four nutrient levels viz., S_1 -75 %, S_2 -100 %, S_3-125 % water soluble fertilizer through drip system and S_4 - conventional method of irrigation and fertilizer application. Here, 75 % of the P as basal and remaining 25 % P as water soluble fertilizer and the entire quantity of N and K as water soluble fertilizer were applied based on fertigation schedule in different split during different stages of crop. The following is the quantity of fertilizers applied as water soluble and normal forms.

100 % Recommended Dose	:	150:75:75 kg of NPK/ha
As water soluble fertilizer	:	150:18.75:75 kg of NPK/ha
As basal application	:	56.25 kg of P_2O_5/ha (75% of P) as single super phosphate

Urea, mono ammonium phosphate and potassium nitrate were used as water soluble fertilizer for N, P and K, respectively. The soil of the experiment field was sandy clay loam in texture, low in available nitrogen (192 kg ha^{-1}), medium in phosphorus (14.8 kg ha^{-1}) and high in potassium (429 kg ha^{-1}) with EC 0.31 dS m^{-1} having pH 8.4. The inter-specific hybrid cotton RCHB 708 was sown in the experiment and

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plant population was maintained in all the plots by necessary gap filling and thinning as per treatment requirement. Physiological characters *viz.,* Crop growth rate (CGR), specific leaf area were recorded. The CGR was calculated as suggested by Watson (1958) using the formula

$$\text{CGR (g m}^{-2}\text{ d}^{-1}) = \frac{W_2 - W_1}{(t_2 - t_1) \times P}$$

Where,

W_1 and W_2 – Dry weight of plants in g at times t_1 and t_2, respectively.

P - Ground area occupied by the plant (m^2)

The SLA was calculated by using the formula of Kvet *et al.* (1971) and expressed in $cm^2\,g^{-1}$.

$$\text{SLA} = \frac{\text{Leaf area plant}^{-1}\text{ (cm}^2)}{\text{Leaf dry weight plant}^{-1}\text{ (g)}}$$

Yield attributes *viz.,* number of sympodial branches, number of bolls and seed cotton yield was recorded. The data were statistically analysed by the analysis of variance method as suggested by Gomez and Gomez (2010).

Results and Discussion

Crop Growth Rate (CGR)

In general, cotton grows at slower rate at initial stage and then grows at faster rate and the decline slowly towards harvest. The data pertaining to crop growth rate (CGR) (g m^{-2} day^{-1}) are depicted in Table 1 and 2. The study crop recorded a faster crop growth rate between 90 – 135 DAS. This is the period where the crop has more functional leaves leading to higher accumulation of photosynthates. The slower CGR at early stage (45 – 90 DAS) could be attributed due to slow initial built up and the same towards harvest could be attributed to the leaf senescence. This is in conformity with findings of Ghule *et al.* (2013).

Owing to favourable growth parameter for the crop geometry of 120 x 60 cm as well as for 125 % RDF, the CGR showed significance for these treatments. More number of plants fully utilizing the natural and applied resources in the former and the favourable response of Bt cotton to higher nutrients in the later could be attributed as the reason for such significant response. The LAI got fovourably increased with increased application of nutrients especially N as has been observed by Dagdelen *et al.* (2009). The favourable response of physiological parameters for the increased application of NPK was also reported by Ayyadurai (2013). The conventional irrigation and fertilizer application resulted in poor physiological attributes as concluded by Veeraputhiran *et al.* (2002).

Specific Leaf Area (SLA)

Specific leaf area (SLA) is a function of individual leaf size. An optimum leaf area / SLA is conducive for maximum carbon assimilation. Crop geometry showed marked variation on SLA during both the years of study (Table 3, 4 & 5). Wider spacing of 150 × 90 cm (M_4) registered maximum SLA for the respective stages over the years. The results are in confirmation with those of

Table 1. Influence of crop geometry and drip fertigation on crop growth rate (g m^{-2} d^{-1}) of Bt cotton

Treatments	2012 -13			2013-14		
	45-90 DAS	90-135 DAS	135-Harvest	45-90 DAS	90-135 DAS	135-Harvest
Crop geometry						
M_1	3.93	9.21	3. 20	4.14	8.54	3.35
M_2	3.16	9.15	2.69	3.29	8.97	2.86
M_3	3.30	8.80	2.75	3.63	8.35	3.06
M_4	2.67	7.73	2.07	2.72	7.29	2.48
SEd	0.13	0.32	0.22	0.16	0.28	0.14
CD (P = 0.05)	0.31	0.78	0.55	0.39	0.69	0.34
Fertilizer levels						
S_1	3.02	8.29	2.54	3.27	7.93	2.55
S_2	3.60	8.99	2.89	3.80	8.52	3.35
S_3	3.64	9.71	3.11	3.93	9.25	3.51
S_4	2.79	7.89	2.18	2.77	7.44	2.34
SEd	0.12	0.31	0.15	0.13	0.33	0.14
CD (P = 0.05)	0.28	0.76	0.36	0.32	0.80	0.35
Interaction	S	NS	NS	S	NS	NS

Amanullah *et al.* (2007) and concluded that SLA was higher in thinner density as compared to thicker density in maize. In both the year of experimentation, significant interaction was noticed between crop geometry and fertilizer levels in recording SLA. Wider crop geometry of 150 x 90 cm (M_4) with application of RDF @ 125 % as water soluble fertilizer (S_3) recorded higher SLA. However, comparable SLA was observed with 150 x 90 cm (M_4) with application of RDF @ 100 % as water soluble fertilizer (S_2), and it was on par with 120 x 90 cm (M_2) with application of RDF @ 125 % as water soluble fertilizer. Obviously, the minimum SLA was noticed with closer crop geometry of 120 x 60 cm with conventional irrigation and fertilizer application during both the years of study. The decreased SLA under 120 × 60 cm indicated that individual leaves received more solar radiation (Bullock *et al*., 1988).

Crop Geometry	Fertilizer level
M_1 – 120 x 60 cm	S_1 – 75 % RDF as WSF (75 % P applied as basal)
M_2 – 120 x 90 cm	S_2 – 100 % RDF as WSF (75 % P applied as basal)
M_3 – 150 x 60 cm	S_3 – 125 % RDF as WSF (75 % P applied as basal)
M_4 - 150 x 90 cm	S_4 – Conventional irrigation and fertilizer application

Table 2. Crop geometry and drip fertigation interaction on crop growth rate (g m^{-2} d^{-1}) of Bt cotton between 45 and 90 DAS

Treatments	2012-13					2013-14				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	3.58	3.11	3.04	2.37	3.02	3.92	3.02	3.70	2.42	3.27
S_2	4.09	3.55	3.48	3.28	3.60	4.40	3.73	3.68	3.38	3.80
S_3	4.22	3.41	3.53	3.41	3.64	4.64	3.77	3.91	3.42	3.93
S_4	3.82	2.58	3.14	1.61	2.79	3.61	2.62	3.21	1.66	2.77
Mean	3.93	3.16	3.30	2.67		4.14	3.29	3.63	2.72	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.13	0.12	0.22	0.23		0.16	0.13	0.19	0.21	
CD (P=0.05)	0.31	0.28	0.49	0.49		0.39	0.32	0.44	0.46	

Yield attributes of Bt cotton

The most critical yield attribute that decides the yield of cotton is the number of sympodial branches plant^{-1}. Yield contributing characters, wider spacing exhibited significantly better values than closer spacing. The sympodial branches were higher with when plant spacing increased to 90 cm. Since, it is long duration interspecific hybrid Bt cotton produced more sympodial branches requires sufficient inter and intra row spacing (Table 6 and 7). The lesser number of sympodial branches plant^{-1} recorded with 120 x 60 cm crop geometry. This results are line with the finding of Majunatha *et al.,* (2010); Bhalerao *et al.,* (2010). Drip fertigation treatments produced higher sympodial branches plant^{-1} as compared to surface irrigation with soil application of fertilizer was reported by Sampathkumar (2009). When wider crop geometry coupled with higher amount nutrient produced more number of sympodial branches plant^{-1} (Bhalerao *et al.* 2010).

Total number of bolls in cotton plant at maturity is an important yield component. Significantly higher number of bolls plant $^{-1}$ was registered with crop geometry of 150 x 90 cm. This may be attributed to the fact that cotton plants were grown wide apart and due to availability of more nutrients and ample space, it is common to get more number of bolls. This is in confirmation with the earlier reports of Krishnaswamy and Iruthiayaraj (1983) that higher number of fruiting points was recorded with plant density of 3333 plants ha^{-1} as compared to 6666 plants ha^{-1}. The ability of cotton crop to produce and support more number of bolls depends on dry matter accumulation and its translocation to sink. Square formation and subsequent development of bolls and their retention in plant are controlled by soil moisture conditions (Turner *et al*., 1986). Similarly, Grieesha (2003) observed significantly higher values of bolls per plant due to drip fertigation than conventional method of irrigation.

Seed cotton yield

Maximum yield potential of crop can be realized by adopting suitable agronomic practices like, maintaining appropriate crop geometry, nutrient and irrigation practices. The plant spacing of 120 x 90 cm had higher seed cotton yield over closer and wider spacing. All the yield attributing characters were lesser with closer spacing though the plant population was higher under the 120 x 60 cm (Table 6 and 7). The reason might be due to significantly higher values of yield attributes under wider plant spacing, which increased the yield of Bt cotton. This result is in conformity with the finding of Bhalerao *et al.* (2010).

Table 3. Influence of crop geometry and drip fertigation on specific leaf area (cm^2 g^{-1}) of Bt cotton

Treatments	2012-13			2013-14		
	45 DAS	90 DAS	135 DAS	45 DAS	90 DAS	135 DAS
Crop geometry						
M_1	217.7	294.0	305.9	242.0	306.0	319.7
M_2	233.4	329.8	340.0	232.0	328.7	338.7
M_3	230.0	323.6	331.6	238.2	320.1	330.6
M_4	242.3	346.4	355.1	244.5	345.1	357.6
SEd	7.9	11.4	9.2	8.7	8.5	8.3
CD (P = 0.05)	NS	27.8	22.5	NS	20.9	20.3
Fertilizer levels						
S_1	228.8	306.4	320.4	230.3	307.3	318.3
S_2	233.6	338.7	348.0	241.9	340.9	354.6
S_3	245.3	357.6	367.4	258.3	358.6	371.3
S_4	215.7	291.1	296.8	226.2	293.1	302.3
SEd	8.7	13.2	12.0	8.5	12.0	12.7
CD (P = 0.05)	21.3	32.4	29.5	20.7	29.4	31.1
Interaction	NS	S	S	NS	S	S

Drip fertigation at 125 per cent RDF with WSF recorded significantly higher seed cotton and it was comparable with 100 percent RDF as water soluble fertilizer. Pandiaraj (2008) also reported that drip fertigation had greater advantages and increased seed cotton yield as compared to surface irrigation and broadcast application of fertilizer nutrients. Increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with

Table 4. Crop geometry and drip fertigation interaction on specific leaf area (cm^2 g^{-1}) of Bt cotton (2012-13)

Treatments	90 DAS					135 DAS				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	272.1	317.4	309.4	326.9	306.4	286.5	334.1	322.5	338.6	320.4
S_2	308.5	341.6	334.7	370.2	338.7	322.5	350.6	341.6	377.3	348.0
S_3	348.8	352.5	344.1	384.9	357.6	358.1	370.5	352.4	388.4	367.4
S_4	246.5	307.9	306.3	303.7	291.1	256.5	304.9	310.0	315.9	296.8
Mean	294.0	329.8	323.6	346.4		305.9	340.0	331.6	355.1	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	11.4	13.2	14.0	13.2		9.2	12.0	11.8	10.4	
CD (P=0.05)	27.8	32.4	32.1	30.5		22.5	29.5	27.0	24.3	

Table 5. Crop geometry and drip fertigation interaction on specific leaf area (cm^2 g^{-1}) of Bt cotton (2013-14)

Treatments	90 DAS					135 DAS				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	302.2	310.9	305.0	311.0	307.3	312.9	321.7	314.7	324.0	318.3
S_2	315.2	347.9	329.8	370.9	340.9	329.0	359.3	344.3	385.9	354.6
S_3	337.5	361.7	342.9	392.3	358.6	352.5	371.3	355.3	406.0	371.3
S_4	269.3	294.4	302.7	306.1	293.1	284.3	302.6	308.0	314.5	302.3
Mean	306.0	328.7	320.1	345.1		319.7	338.7	330.6	357.6	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	8.5	12.0	12.3	10.7		8.3	12.7	12.5	10.5	
CD (P=0.05)	20.9	29.4	27.8	24.9		20.3	31.1	28.4	24.6	

frequent nutrient supply by fertigation consequently led to better formation and translocation of assimilates from source to sink causing increased seed cotton yield under fertigation.

Interactions among the treatments were significant on seed cotton yield. The combination of 120 x 90 cm crop geometry and application of 125 % RDF as water soluble fertilizer recorded higher seed cotton yield and the same was statistically comparable with 120 x 90 cm with 100 % RDF as water soluble fertilizers. Sufficient inter and intra row spacing and higher amount of available nutrient enhanced the yield of interspecific hybrid Bt cotton. Lower yield was recorded with 150 x 90 cm with conventional practices of irrigation and fertilizer application and it mainly due to could not compensate for the loss in number of plants per hectare and thus, recorded lower seed cotton yield per hectare. Similar results were observed by Narayana *et al*. (2008). It can be concluded that 120 x 90 cm with 125 % or 100 % RDF as water soluble fertilizer resulted in higher economic yield in inter specific hybrid Bt cotton.

Table 6. Effect of crop geometry and drip fertigation on yield attributes and yield of Bt cotton during 2012-13

Treatments	Sympodial branches plant^{-1}					No. of bolls plant^{-1}					Seed cotton yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	18.3	21.6	19.2	22.8	20.5	43.9	62.0	51.4	65.3	55.6	2296	2554	2043	1800	2173
S_2	18.9	24.4	21.7	24.6	22.4	52.2	70.4	58.4	75.4	64.1	2842	2943	2346	2027	2539
S_3	20.0	26.1	23.4	27.1	24.1	51.5	75.6	60.2	80.8	67.0	2723	3066	2477	2361	2657
S_4	17.1	19.5	18.2	20.9	18.9	41.2	52.4	45.5	57.6	49.2	2016	1968	1848	1756	1897
Mean	18.6	22.9	20.6	23.9		47.2	65.0	53.9	69.8		2469	2633	2179	1986	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE_d	0.47	0.49	0.70	0.70		2.1	2.5	2.6	2.4		100	99	123	123	
CD(P=0.05)	1.15	1.20	1.58	1.57		5.1	6.1	6.0	5.6		244	242	279	280	

Table 7. Effect of crop geometry and drip fertigation on yield attributes and yield of Bt cotton during 2013-14

Treatments	Sympodial branches plant^{-1}					No. of bolls plant^{-1}					Seed cotton yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	18.3	21.8	19.2	22.2	20.4	48.0	63.5	53.2	65.7	57.6	2496	2763	2233	1600	2273
S_2	18.4	24.7	23.1	25.1	22.8	56.2	71.8	60.2	74.5	65.7	3067	2990	2536	1990	2646
S_3	19.5	26.6	24.5	27.4	24.5	52.3	77.9	63.6	82.0	69.0	2938	3286	2667	2167	2764
S_4	17.1	21.0	17.2	21.3	19.1	40.6	51.9	44.3	53.3	47.5	2175	2131	2038	1523	1967
Mean	18.3	23.5	21.0	24.0		49.3	66.3	55.3	68.9		2669	2792	2369	1820	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SE_d	0.46	0.51	0.86	0.84		2.1	2.6	2.9	2.7		101	106	125	123	
CD(P=0.05)	1.13	1.25	1.28	1.86		5.1	6.5	6.6	6.2		247	259	285	282	

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