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AGRONOMY

Growth, Productivity and Quality of Bt and non-Bt Cotton Hybrids (*Gossypium hirsutum* L.) as Influenced by Environment

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ABSTRACT

A field experiment was conducted to study the effect of environments (timely sown and late sown) on crop phenology development, yield and fibre development of Bt and non-Bt cotton hybrids viz., G cot hy 8 BG II (Bt), G cot hy12 (non-Bt), NCS 145 BG II (Bt), DHH 263 (non-Bt), Ankur 3028 BG II (Bt) and LHH 144 (non-Bt) commonly grown in different ecological zones of the country. Results revealed that timely sown crop produced significantly higher seed cotton yield (14.80 q/ha) than the late sown crop (8.00 q/ha) due to petite crop canopy, lesser number of sympods, bolls and lower boll weight per plant. The maximum seed cotton yield was recorded with Ankur 3028 BG II (14.72 q/ha) which was significantly superior to all other Bt as well as non-Bt cotton hybrids. Further, LHH 144 (12.94 q/ha) and G cot hy 8 BG II (12.88 q/ha) recorded significant edge over rest of the hybrids. Among the rest of the hybrids, G cot hy 12 (10.81 q/ha), DHH 263 (9.09 q/ha) and NCS 145 BG II (7.99 q/ha) followed significantly diminishing order in seed cotton yield. The higher yield in Ankur 3028 BG II, LHH 144 and G cot hy 8 BG II was mainly attributed to higher sympods, boll number and boll weight per plant. The fibre length was also significantly more in timely sown crop as compared to late sown crop. Among the hybrids, Ankur 3028 BG II registered significantly more fibre length than rest of the hybrids.

Highlights

- Harvest potential of cotton can only be apprehended by timely sowing of the crop.
- Amidst the hybrids, predilection must be given to Ankur 3028 BG II trailed by LHH 144 and G cot hy 8 BG II.

Keywords: Cotton hybrids, environment, fibre length, GDD, *Gossypium hirsutum*, growth, productivity

Cotton is primarily used in textile industries, fishing net, coffee filter, tents, cotton paper and book binding. The cotton seed is ginned to produce cotton seed oil which after refining is consumed by human beings and its meal is fed to ruminant live stock. Cotton productivity was drastically reduced in 1990s in north India and Punjab in particular due to severe incidence of bollworms particularly American bollworm (*Heliothis armigera*). The Bt cotton was introduced to reduce the heavy reliance on pesticides as it was resistant to the attack of American, pink and spotted bollworms and tobacco caterpillar; and to sustain the cotton production and productivity. There was an encouraging response of farmers towards Bt cotton cultivation while replacing traditional varieties and hybrids at stroke, just to escape bollworm menace and to achieve potential yield (Thimmareddy *et al.* 2013). During the 13-year span from 2002 to 2014, cotton production had tripled from 13.6 million bales to 39 million bales due to commercialization of Bt cotton in India, which increased 230-fold from 50,000 hectares in 2002 to 11.6 million hectares in 2014, covering 95 per cent of the total 12.25 million hectares of cotton. India has doubled its market share of global cotton production representing a quarter of the total global cotton production from 12 per cent in 2002 to 25 per cent in 2014 due to increase in area as well as productivity of cotton (Choudhary and Gaur 2015).

Cotton plant with indeterminate growth habit follows a typical sigmoid curve with a relatively slow start during emergence and root growth followed by exponential increase in growth rate during canopy formation, flowering and boll development and finally by a slowing down during the boll maturation phase (Zhao *et al.* 2003). Yield is essentially controlled by the genetic potential of plant and the environment. These, in turn, are further modified by cultural practices. At a more agronomic level, yield may be considered in terms of its major components: boll number per unit area and the average boll weight. The growth of the plant and development of bolls depends on the production of dry matter by photosynthesis and therefore, the production of dry matter is the fundamental process of yield. These processes require sun light, water and adequate plant nutrition. The carbohydrate products of photosynthesis need to be protected from pests.

Cotton is cultivated in three distinct agro-ecological zones; north, central and south, of the country. The northern zone comprising states of Punjab, Haryana and Rajasthan has highest percentage of irrigated area, while the irrigated area is much lower in the southern zone comprising states of Telangana, Andhra Pradesh, Karnataka and Tamil Nadu and the lowest being in the central zone comprising states of Gujarat, Maharashtra and Madhya Pradesh which has nearly 60 per cent of cotton area of our country. In Punjab, cotton is grown in the Arid belt (South-Western Punjab) and sown during April to mid May. Most often, its sowing gets delayed on account of late wheat harvesting and release of water in the tributaries for applying pre-sowing irrigation. The environmental conditions vary considerably from Aril to end May under Punjab conditions. The cotton is highly sensitive to environment particularly during early stage. The behaviour and productivity of different cotton hybrids may vary under different growing conditions. The behaviour of hybrids selected from different ecological zones may vary under different growing environments. Hence, there is a need to identify suitable cotton hybrids for timely sown as well as late sown conditions. In view of the above discussed complexities, research investigation was planned to study the behavior of Bt and non-Bt cotton hybrids obtained from different ecological zones of India in Punjab under varied environments for sustaining the cotton productivity.

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Area of Cotton Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *Kharif* 2012 in a factorial randomized complete block design (RCBD) with three replications. The treatments comprised of two hybrids from Gujrat (G cot hy 8 BG II Bt and G cot hy 12 non-Bt) representing central zone, two from Karnataka (NCS 145 BG II Bt and DHH 263 non-Bt) representing south zone and two from Punjab (Ankur 3028 BG II Bt and LHH 144 non-Bt) representing north zone under two environments such as timely sowing and three weeks later. The soil of the experimental field was sandy loam in texture, neutral in pH, low in available nitrogen and medium in available phosphorus as well as potassium. The crop was sown on 5th May (timely sown) and three weeks later on 26th May (late sown), during 2012. Crop was raised as per the package of practices recommended by Punjab Agricultural University, Ludhiana. Data on seed cotton yield (q/ha), plant height, number of sympods per plant, boll number per plant, boll weight (g) and ginning out-turn (GOT) per cent were recorded.

Ginning out-turn (GOT): Twenty gram sample of seed cotton from each plot was taken and ginning was done. The weight of lint in each sample was recorded and used for calculating ginning out-turn with following formula:

Ginning out-turn (GOT) (%) =

$$\frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

Growing degree days (GDD): GDD were computed using the temperature data available from the meteorological observatory during the growing season as per the following formula:

$$\text{Growing Degree Days (GDD)} = \frac{T_{max} + T_{min}}{2} - T_{base}$$

Fibre length: It was determined by using the method of Gipson and Ray (1969). The periodic fibre length was measured 7, 14, 21 and 31 days after anthesis. The bolls were carefully opened with a scalpel and intact locules were taken out of each boll and dropped in a beaker of boiling water for 2-5 minutes in order to separate seeds and fibres for fibre length measurement. These seeds were fanned out by placing the seed on convex side of watch glass under a fine stream of water. Fibre length was determined measuring from the ovule epidermis to the tip of fibre produced on the chalazal end of the ovule with calipers.

RESULTS AND DISCUSSION

Cotton is greatly influenced by the environmental conditions and the yield potential of different genotypes is realized only under favourable environmental conditions. Furthermore, different cotton genotypes perform in a different way under different environmental conditions. The behaviour of different cotton hybrids under varying environmental conditions has been discussed below:

Plant height

The data pertaining to plant height (Table 1) revealed that timely sown cotton attained significantly more height than that of late sown cotton. More plant height of timely sown cotton might be due to favourable environmental conditions during early phases of crop growth. Among the hybrids, Bt cotton hybrid Ankur 3028 BG II recorded significantly more plant height over all other hybrids. Among the remaining hybrids, LHH 144 and G cot hy 12 were statistically at par with each other and both attained significantly more plant height than the rest of the hybrids. Further, NCS 145 BG II and G cot hy 8 BG II being statistically at par with each other registered significantly more plant height than DHH 263. Brar and Sarlach (2012) also found similar results.

Number of sympods

The sympodial branches showed similar behavior to that of plant height i.e. significantly more number of branches with timely sown cotton than that under late sown environment (Table 1). Results indicated that timely sowing provided favourable conditions for early growth which brought about higher number of sympods than late sown crop. Results are in line with the findings of Pettigrew (2002), Hallikeri (2009). Among the hybrids, the large number of sympods were recorded in Ankur 3028 BG II, which being statistically at par with LHH 144 recorded significantly higher number of sympods than all other hybrids. In addition, LHH 144, G cot hy 8 BG II and NCS 145 BG II were statistically at par with each other but registered significantly higher number of sympods than G cot hy 12 and

Table 1: Effect of sowing time on seed cotton yield and yield components of different cotton hybrids

Treatment	Plant height (cm)	Sympods/plant	Boll No./plant	Boll weight (g)	GOT (%)	Seed cotton yield (q/ha)
Sowing time						
Timely sown	119.3	18.81	28.09	4.02	32.67	14.80
Late sown	100.0	17.00	15.54	3.96	32.73	8.00
SEm±	2.79	0.48	1.09	0.13	0.89	0.45
CD (P=0.05)	9.3	1.62	3.46	NS	NS	1.46
Hybrids						
LHH 144	113.7	19.73	24.11	4.27	32.60	12.94
Ankur 3028 BG II	129.2	20.84	25.34	4.17	32.53	14.72
DHH 263	90.3	14.11	20.05	3.98	32.88	9.09
NCS 145 BG II	106.4	18.45	9.22	3.65	32.25	7.99
G cot hy 12	112.8	15.61	24.83	3.81	32.45	10.81
G cot hy 8 BG II	105.6	18.69	27.34	4.08	33.48	12.88
SEm±	1.93	0.52	0.99	0.07	0.76	0.38
CD (P=0.05)	6.2	1.76	3.29	0.26	NS	1.24

DHH 263 which were further statistically at par with each other (Table 1). Ankur 3028 BG II and LHH 144 produced higher number of sympods probably due to adoption of these hybrids to environment. Similar results were reported by Brar and Sarlach (2012).

Boll number

It is among the useful indices determining the yield level of indeterminate crop. Under timely sown environment, plants produced significantly higher number of bolls per plant than late sown environment indicating the beneficial effect of timely sown crop with enhanced boll number by 80.8 per cent (Table 1). The results thus clearly elucidate that the test hybrids performed well under timely sown conditions/environment but with delay in sowing, the crucial yield contributing character boll number reduced discernibly. Hallikeri (2009) also found higher number of bolls with timely planted cotton as compared to late planted cotton. Among the hybrids, G cot hy 8 BG II (27.34), Ankur 3028 BG II (25.34), G cot hy 12 (24.83) and LHH 144 (24.11) were statistically at par with each other and all these hybrids produced significantly higher number of bolls per plant than DHH 263 (20.05) and NCS 145 BG II which could bear only 9.22 bolls per plant which was statistically lower than all other hybrids, thus giving useful information that NCS 145 BG II was unsuitable under Punjab conditions. Results are confirmatory with the findings of Brar and Sarlach (2012).

Boll weight

Boll weight is another valuable character considered crucial in determining economic yield. The boll weight did not vary much under timely sown and late sown environments and the corresponding average values were 4.02 g and 3.96 g, respectively (Table 1). However, the results further entail that boll weight varied significantly with the hybrids. LHH 144 (4.27) being statistically at par with Ankur 3028 BG II (4.17), G cot hy 8 BG II (4.08) produced significantly higher boll weight than rest of the hybrids. Further, Ankur 3028 BG II and G cot hy 8 BG II registered significant edge over G cot hy 12 (3.81) and NCS 145 BG II (3.65) which recorded the least boll weight. Higher boll weight in LHH 144 and Ankur 3028 BG II might be due to adoption of these hybrids to the prevailing environment.

Fibre length

Data on fibre length at different time-periods (7, 14, 21 and 31 days after anthesis) were recorded (Table 2). Results revealed that fibre length was significantly more in timely sown crop than late sown environment at all the observational periods. The fibre length at 31 days after anthesis was 15.15 per cent more in timely sown condition than in late sown condition. More fibre length in timely sown cotton may be attributed to more favourable conditions with timely own cotton as compared to late sown crop. Nehra and Matish (2001), Hallikeri (2009) also reported more fibre length of cotton by timely planting as compare to late planting. Among the hybrids, at 7 days after anthesis, LHH

Table 2: Effect of sowing time on fibre length (mm) of different cotton hybrids

Treatment	7 days after anthesis	14 days after anthesis	21 days after anthesis	31 days after anthesis
Sowing time				
Timely sown	4.33	21.38	23.69	26.91
Late sown	2.61	18.40	20.88	23.37
SEm±	0.22	0.79	0.79	0.99
CD (P=0.05)	0.71	2.55	2.60	3.06
Hybrids				
LHH 144	4.17	20.50	24.67	28.17
Ankur 3028 BG II	4.17	17.00	18.50	24.50
DHH 263	2.00	20.50	21.50	25.17
NCS 145 BG II	3.67	20.34	22.50	25.33
G cot hy 12	3.67	20.84	24.50	25.50
G cot hy 8 BG II	3.17	20.17	22.00	22.17
SEm±	0.18	0.67	0.71	0.76
CD (P=0.05)	0.59	2.16	2.33	2.42

Table 3: Growing degree days in timely sown cotton hybrids

Hybrid	Planting to emergence		Emergence to 1st leaf		Ist to 2nd leaf		2nd to 3rd leaf		3rd leaf to squaring		Squaring to flowering		Flowering to 1st boll opening		1st boll opening to 1st picking	
	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD
LHH 144	5	108.5	7	157.5	4	91.6	4	106.6	30	750.0	4	90.4	53	1020.2	53	514.1
Ankur 3028 BG II	4	87.6	7	150.5	4	90.0	4	106.4	34	768.4	16	355.2	59	1008.9	33	320.1
DHH 263	5	108.5	6	129.0	4	90.0	5	133.25	31	815.3	7	150.5	57	1168.5	46	446.2
NCS 145 BG II	4	87.6	9	216.0	3	68.7	5	122.5	32	723.2	9	176.4	61	1073.6	38	368.6
G Cot hy 12	5	108.5	6	129.0	3	61.3	6	159.9	34	802.4	12	285.6	66	1125.3	30	291.0
G Cot hy 8 BG II	4	87.6	8	180.0	4	91.6	3	79.8	37	780.7	10	238.0	67	1105.5	29	281.3

Table 4: Growing degree days in late sown cotton hybrids

Hybrid	Planting to emergence		Emergence to 1st leaf		1st to 2nd leaf		2nd to 3rd leaf		3rd leaf to squaring		Squaring to flowering		Flowering to 1st boll opening		1st boll opening to 1st picking	
	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD	Days	GDD
LHH 144	4	81.2	7	173.6	4	96.0	8	181.6	26	574.0	11	214.0	43	709.5	46	446.2
Ankur 3028 BG II	4	81.2	7	163.8	4	95.2	8	190.8	28	525.0	15	301.5	48	993.6	52	504.4
DHH 263	4	81.2	7	162.4	6	142.8	8	190.8	28	525.0	9	179.1	50	830.0	40	388.0
NCS 145 BG II	4	81.2	4	92.8	7	168.0	9	225.6	32	600.0	9	179.1	55	968.0	35	339.5
G Cot hy 12	4	81.2	3	63.6	8	192.0	8	181.6	34	676.6	12	232.8	55	880.0	25	242.5
G Cot hy 8 BG II	4	81.2	4	92.8	7	168.0	7	166.9	34	676.6	12	232.8	50	875.0	24	232.8

144, Ankur 3028 BG II hybrids being statistically at par with G cot hy 12 and NCS 145 BG II recorded significantly more fibre length than G cot hy 8 BG II and DHH 263 which recorded the least fibre length. At 14 days after anthesis, all the hybrids observed significantly more fibre length than Ankur 3028 BG II. At 21 days after anthesis, LHH 144 and G cot hy 12 being statistically at par with NCS 145 BG II recorded significantly more fibre length than all other hybrids. Ankur 3028 BG II gained least and significantly lesser fibre length than all other hybrids. At 31 days after anthesis, the maximum fibre length was recorded in LHH 144 (28.17 mm) and that was significantly superior than all other hybrids. Further, all the hybrids recorded significantly more fibre length than G cot hy 8 BG II (22.17 mm) which recorded the least fibre length.

Growing degree days (GDD)

In timely sown plots, minimum heat units required for emergence were recorded in Ankur 3028 BG II, NCS 145 BG II and G cot hy 8 BG II (87.6 GDD) and maximum growing degree days were observed in LHH 144, DHH 263 and G cot hy 12 (108.5 GDD) which has quite favorable effect on growth and development of crop. For appearance of 1st leaf from emergence, maximum heat units (216 GDD) were consumed by NCS 145 BG II and minimum (129 GDD) were utilized by DHH 263 and G cot hy 12. However, for the appearance of 2nd leaf from 1st leaf, G cot hy 12 required minimum heat units (61.3 GDD) and maximum heat units were needed by LHH 144 and G cot hy 12 (91.6 GDD). From 2nd leaf to 3rd leaf, maximum heat units (159.9 GDD) were consumed by G cot hy 12 and minimum (79.8 GDD) by G cot hy 8 BG II. From 3rd leaf to squaring, maximum heat units accumulated (815.3 GDD) were by DHH 263 and minimum by NCS 145 BG II (723.2 GDD). From squaring to flowering, the maximum heat units consumed (355.2 GDD) were by Ankur 3028 BG II and minimum (90.4 GDD) by LHH 144. Further, from flowering to 1st boll opening, hybrid DHH 263 accumulated maximum heat units (1168.5 GDD), whereas, hybrid Ankur 3028 BG II accumulated minimum heat units (1008.9 GDD). At the end, from 1st boll opening to 1st picking, maximum heat units accumulated were by LHH 144 (514.1 GDD) and minimum (281.3 GDD) by G cot hy 8 BG II.

In late sown plots, heat units recorded for emergence were (81.2 GDD) for all the hybrids. Minimum heat units accumulated for appearance of 1st leaf were (63.6 GDD) by G cot hy 12 and maximum by LHH 144 (173.6 GDD). From 1st leaf to 2nd leaf, minimum heat units recorded were (95.2 GDD) by Ankur 3028 BG II and maximum (192 GDD) by G cot hy 12. From 2nd leaf to 3rd leaf, maximum heat units were (225.6 GDD) by NCS 145 BG II and minimum (166.9 GDD) by G cot hy 8 BG II. From 3rd leaf to squaring, maximum heat units were required (676.6 GDD) by G cot hy 8 BG II and G cot hy 12 and minimum by Ankur 3028 BG II and DHH 263 (525 GDD). From squaring to flowering, the maximum heat units consumed (355.2 GDD) were by Ankur 3028 BG II and minimum (90.4 GDD) by LHH 144. Further, from flowering to 1st boll opening, hybrid DHH 263 accumulated maximum heat units (1168.5 GDD), whereas, hybrid Ankur 3028 BG II accumulated minimum heat units (1008.9 GDD). From 1st boll open to 1st picking, maximum heat units were consumed by Ankur 3028 BG II (504.4 GDD) and minimum (232.8 GDD) by G cot hy 8 BG II. The main reason for giving high seed cotton yield under timely sown environment is more accumulation of heat unit as compared to the late sown cotton.

Seed cotton yield

The seed cotton yield decreased discernibly under late sown conditions as compared to timely sown conditions (Table 1). The cotton under timely sown conditions produced 85 per cent higher seed cotton yield than late sown cotton. The low yield under late sown environment was chiefly because of short crop canopy, lesser number of sympods and boll per plant. The dry matter accumulation by photosynthesis and carbohydrates which are translocated to the developing fruits are greatly influenced by the sunlight and temperature. These parameters may be affected under late sown environment leading to low yield. Nehra and Matish (2001), Pettigrew (2002), Hallikeri (2009), Singh (2010) also reported yield advantage by early sowing of cotton due to superiority in yield attributes as compared to late sowing.

Among hybrids, the highest seed cotton yield was accrued with Ankur 3028 BG II (14.72 q/ha) which was significantly higher than all other hybrids. In addition, LHH 144 (12.94 q/ha) and G cot hy 8 BG II (12.88 q/ha) obtained significantly higher yield than rest of the hybrids, viz., G cot hy 12 (10.81 q/ha), DHH 263 (9.09 q/ha) and NCS 145 BG II (7.99 q/ha). Further, G cot hy 12, DHH 263 and NCS 145 BG II followed the diminishing seed cotton yield with significant difference among each other (Table 1). The higher yield level in Ankur 3028 BG II hybrid was mainly attributed due to highest boll number per plant and maximum plant height along with appreciable sympods. The other best hybrids LHH 144 and G cot hy 8 BG II were also having appreciable number of sympods, boll number per plant and boll weight. The hybrids viz., DHH 263 and NCS 145 BG II were not found suitable for high yield realization under Punjab conditions. The results of the study are in line with the findings of Brar and Sarlach (2012).

Ginning out-turn

Ginning out-turn was not much influenced either with the time of sowing or by the different hybrids. It was more or less similar and fell in a narrow range varying from 32.67 to 32.73 per cent under different sowing environments and 32.25 to 33.48 per cent with different hybrids.

CONCLUSION

On the basis of results obtained from the field experiment, it can be concluded that higher seed cotton yield can only be obtained with timely sowing of cotton crop, as under late sown conditions, substantial reduction in yield occurred on account of less accumulated heat unit adversely affecting the yield contributing characters. Among hybrids, preference should be given to Ankur 3028 BG II followed by LHH 144 and G cot hy 8 BG II, while the other hybrids proved less productive.

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