Indian Journal of Agricultural Sciences **81** (9): 871–4, September 2011

Growth, yield and quality of *Bt* cotton (*Gossypium hirsutum*) hybrid under varied planting patterns, NPK levels and seasonal variations*

K SANKARANARAYANAN[1], C S PRAHARAJ[2], P NALAYINI[3] and N GOPALAKRISHNAN[4]

Regional Station, Central Institute For Cotton Research, Maruthamalai Main Road, Coimbatore 641 003

Received: 26 May 2010; Revised accepted: 2 May 2011

Key words: *Bt* cotton hybrid, NPK levels, Planting pattern, Seasonal variation

Pest control is the major hurdle in cotton cultivation and the yield loss due to pest infestations is estimated to be around 60–70% of the total losses (Puri *et al.* 1999). Before introduction of *Bt* hybrids, the outbreak of insect pests, especially bollworm complex was an important constraint that made the crop non-remunerative since an average farmer in India applies 15–20 sprays to protect cotton from pests in a single crop season. Introduction of *Bt* cotton hybrids came to the rescue by reducing the pest menace to a considerable level, besides revolutionizing cotton production around the globe. Concomitant with the steep increase in adoption and spread of *Bt* cotton, it necessitates in fine tuning the existing input and cultivation practice normally followed based on existing conventional hybrid.

Agronomic performance of transgenic cultivars may vary substantially compared with the non-transgenic cultivars or germplasm lines from which they were originally developed. *Bt* transgenic cotton has shown changes in vegetative and reproductive characteristics (Chen *et al.* 2004), and are compact with optimum number of functional leaves, small in size and thus, are more efficient in converting assimilates to the economic parts, the cotton bolls. Thus, higher population of these plants could be accommodated in an area by adopting closer row spacing because of altered morphoframe following incorporation of *Bt* gene. *Bt* hybrids recorded 6.95% less plant height, 10.81% less leaf area index (LAI) than non-*Bt* hybrids (Rekha 2007). In addition, crop response to increased levels of inputs was also apparent for higher economic production. Vishwanath (2007) recorded significantly higher seed cotton yield 150% RDF (2 420 kg/ha) as compared to control (2 139 kg/ha). Since there is a need to refine/modify the crop geometry and nutrient need in this hi-tech *Bt* cotton hybrid (Venugopal 2004) to realize its full yield potential, a field trial was carried out to optimize plant population and NPK levels in the popular *Bt* cotton hybrid.

The present experiment was carried out at New Area farm of Regional Station, Central Institute for Cotton Research, Coimbatore, Tamil Nadu during the fall season (August to February) of 2003–05 under irrigated condition. The soil was clay loam in texture, low in available N (233 kg/ha), medium in available P (20.3 kg/ha) and high in available K (1050 kg/ha) with a *p*H 8.5 and EC 0.23 dS/m. The experiment was laid out in a factorial randomized block design with three replications. The treatments comprised three planting pattern (90 cm × 60 cm with 18500 plants/ha, 90 cm × 45 cm with 24 700 plants and 75 cm × 60 cm with 22 200 plants) with three NPK levels of 100% (90:45:45 kg of N, P_2O_5 and K_2O /ha,) 125% (112.5:56:56 kg of N, P_2O_5 and K_2O/ha) and 150% (135:67.5:67.5 kg of N, P_2O_5 and K_2O/ha) of normal recommendation. Half of N and full dose of P and K were applied as the time of planting as per treatment schedules. Remaining half of N was applied at 45 days after planting (DAP) commensurating with earthing up. MECH 162 *Bt* hybrid developed by MAHYCO (P) Ltd was used as test hybrid. Other cultivation practices were adopted uniformly for all the treatments. Pre-emergence application of fluchloralin @1 kg/ha was also applied on the plots, followed by two hand weedings to keep the experimental plot weed free. Growth attributes, yield parameters and seed cotton yield were recorded during the course of investigation. Fibre quality parameters, viz Ginning per cent (GP), seed index, lint index, 2.5% span length, maturity ratio, uniformity ratio, micronaire, fibre strength and fibre elongation were also analyzed. Fibre quality index (FQI= LT/vM, where L, 2.5% span length (mm), T, fibre bundle tenacity at 3.2 mm gauge (g/tex) and M, micronaire value), count (C=0.196 FQI - 16)

*Short note

[1,3]Senior Scientist (Agronomy) (e mail: sankaragro@gmail.com, nalayiniganesh@gmail.com); CICR, RS, Coimbatore, Tamil Nadu 641 003;

[2]Principal Scientist (Agronomy) (e mail: cspraharaj@gmail.com), Indian Institute of Pulses Research, Kanpur, Uttar Pradesh 208 024;

[4]Assistant Director General (Commercial Crops), (e mail: gopalcotton@gmail.com), ICAR, New Delhi.

and count strength product (CSP=1.740 FQI + 1600) were also worked out. The quality parameters (except GP, seed index and lint index) were analyzed by using high volume instruments (HVI, Statex- Fibrotex model). Pooled analysis was made from two years data to assess the effect of spacing and fertilizer levels on growth characters, yield attributes, yield, quality and other parameters. Economics was also calculated on the basis of prevailing market price of inputs and outputs.

Planting of *Bt* cotton hybrid under different row spacing (90 cm × 60 cm, 90 cm × 45 cm and 75 cm × 60 cm) significantly influenced leaf area index (LAI), dry biomass both at 90 and 120 DAP, burst bolls/plant, single plant yield and seed cotton yield. Planting at 90 cm × 45 cm registered significantly higher LAI both at 90 (1.8) and 120 (2.3) DAP with maximum biomass of 2 097 kg/ha recorded at 120 DAP. These results were similar to those at 75 cm × 60 cm (LAI of 1.5 at 90 and 2.3 at 120 DAP with a maximum dry weight of 1882 kg/ha at 120 DAP). Higher LAI recorded with closer spacing of 90 cm × 45 cm was mainly attributed to increase in plant density as higher plant density invariably increased LAI. However, these growth characters had no influence on reproductive attributes and seed cotton yield due to interplant competition. Significantly higher yield (2 300 kg/ha) was apparent following planting of MECH-*Bt* hybrid at 75 cm × 60 cm (Table 1). Adoption of existing recommended row spacing of conventional hybrid (90 cm × 60 cm) invariably produced least LAI and lowest dry weight both at 90 and 120 DAP resulting in decline in seed cotton yield. However, significantly higher burst bolls and single plant yields counted with wider row spacing of 90 cm × 60 cm was the result of higher light penetration coupled with good canopy growth and development over closer row spacing. Similarly, a row spacing of 38 cm had more bolls/plant over 19 cm (Jose and Cothren 2000).

Thus, the existing adopted spacing for *Bt* hybrid at 90 cm × 60 cm derived from the conventional hybrids was not optimum for it due to the fact that it produced less relative parameters in respect of LAI, biomass and seed cotton yield over 75 cm × 60 cm (Table 1). Because of more compact growth and dwarf stature, *Bt* cotton occupies less space and favoured for accommodating of higher plant density following its optimization at 22 200 plants/ha maintained by 75 cm × 60 cm over that in 18 500 plants in 90 cm × 60 cm. *Bt* hybrids recorded 7% less plant height and 11% less LAI over non-*Bt* hybrids (Rekha 2007) as all the transgenic *Bt* cotton hybrids were invariably short statured over their non-*Bt* counter parts (Mayee *et al.* 2004). Plant spaced at 75 cm × 60 cm had also a comparable biomass at all the growth stages because of optimal light penetration and higher uptake of major nutrients favoured for increased photosynthetic efficiency and seed cotton yield. Since optimum plant density had a positive correlation with yield, its optimization led to realization of potential crop yield (Venugopal 2004). Similar

Table 1 Effect of planting pattern and NPK levels on growth characters, yield attributes, yield, economics and input-use efficiency of *Bt* cotton hybrid

Treatment	90DAP				120DAP				Attributes of yield				Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	ENUE (kg/₹)	Partial factor productivity (kg/kg)
	Plant height (cm)	LAI	Squares/ plant	Biomass (tonnes/ ha)	Plant height (cm)	LAI	Squares/ plant	Biomass (tonnes/ ha)	Single plant yield (g)	Bolls/ m^2	Boll weight (g)	Seed cotton yield (tonnes/ha)\					
Planting pattern																	
75 cm × 60 cm	62.9	1.5	16.1	0.97	75.2	2.1	12.8	1.88	101.4	63.7	4.4	2.30	46 000	22 373	1.9	0.75	10.4
90 cm × 60 cm	61.7	1.2	15.3	0.65	82.2	1.8	14.4	1.52	112.3	53.5	4.3	1.99	37 600	13 973	1.6	0.65	9.0
90 cm × 45 cm	62.9	1.8	15.9	0.93	84.4	2.3	13.5	2.10	79.4	51.4	4.3	1.88	39 800	16 173	1.7	0.61	8.4
SEd±	4.9	0.1	3.2	0.11	6.7	0.1	2.6	0.16	8.9	3.5	0.1	0.15					
CD (P=0.05)	NS	0.3	NS	0.21	NS	0.3	NS	0.32	18.1	7.2	NS	0.30					
NPK levels																	
100% RD	63.8	1.3	16.0	0.73	82.1	1.8	14.3	1.69	87.3	52.6	4.3	1.86	37 200	14 199	1.6	0.74	10.3
125% RD	62.1	1.5	15.6	0.86	76.7	2.1	14.1	1.79	95.5	55.9	4.4	2.04	40 800	17 173	1.7	0.65	9.1
150% RD	61.6	1.8	15.7	0.96	83.0	2.2	12.1	2.02	110.3	60.1	4.3	2.27	45 400	21 148	1.8	0.61	8.4
SEd±	4.9	0.1	3.2	0.11	6.7	0.1	2.6	0.16	8.9	3.5	0.1	0.15					
CD (P=0.05)	NS	0.3	NS	0.21	NS	0.3	NS	0.32	18.1	7.2	NS	0.30					

ENUE, Economics of nutrient-use efficiency (kg of seed cotton/rupee invested on nutrients) observations were also made by Bhalerao *et al.* (2008), Butter and Singh (2006), Nehra *et al.* (2004) and Vishwanath (2007).

Growth rate calculated in term of absolute (AGR), relative (RGR) and net assimilation rate (NAR) in the crop growth period during 45–90 and 90–120 DAP revealed that the highest CGR (2 and 3.1 g/m^2/day), RGR (62 and 22.3 mg/g/day) and NAR (0.3 and 0.2 mg/cm^2/day) were observed at 75 cm × 60 cm. Although at later stages, RGR was reduced probably due to declining dose at the rate of incremental rate of biomass, yet it played a vital role in partitioning the extra photosynthates towards the developing sink during reproductive development. Besides yield, fibre quality- a genetically controlled attribute was not influenced by different planting patterns.

Similar to planting pattern, NPK levels significantly influenced LAI and biomass at 90 and 120 DAP, single plant yield, bolls/plant and seed cotton yield (Table 1). At all the stages of observation, higher NPK level increased biomass production over the lower level(s). This is in agreement with the pioneer findings revealing a linear increase in biomass following application of nutrients. Significantly higher LAI (1.8 and 2.2) and biomass (0.96 and 2.02 tonnes/ha) at both 90 and 120 DAP, single plant yield (110 g), burst bolls (25.6/plant) and seed cotton yield (2.27 tonnes/ha) were recorded with 150% NPK (135:67.5:67.5 kg N, P_2O_5 and K_2O/ha) to MECH 162 *Bt*. However, these results were on par with 125% NPK (112.5:56:56 kg N, P_2O_5 and K_2O/ha). Increase in observed values in respect of vegetative and reproductive parameters under elevated crop nutrition were attributed to improved foraging ability with better assimilation that enabled the plant to grow favourably. Moreover, higher LAI indicated better photosynthetic efficiency following continuous release of nutrients at higher NPK levels. This was in accordance with the earlier findings of Perumal (1999). Significantly lower observed values in respect of important growth and yield attributes with recommended NPK resulted in decreased seed cotton yield. Increasing NPK levels linearly to the optimum level increased plant growth parameters, yield attributes and yield. A similar result of increased yield following increased NPK application in *Bt* hybrid was also observed by Vishwanath (2007). Thus, performance of *Bt* under varied NPK levels showed under-performance of existing recommended level, if applied to *Bt* hybrids. Instead higher NPK level at 125% showed better performance as it commensurated with the crop demand as a result of altered morphoframe following incorporation of *Bt* gene. Singh and Rao (2002) opined that 125% NPK out yielded over 100% in a popular *Bt* hybrid under rainfed condition.

The interaction effect between the spacing and fertilizer levels was also non-significant. Cotton being a slow growing plant takes almost three months to cover the soil surface because of inherent static nature of its physiological growth and development. Thus, application of higher NPK (150%) to *Bt* hybrid registered highest AGR (2.0 and 3.6 g/m^2/day), RGR (59.5 and 29.5 mg/g/day) and NAR (0.3 and 0.2 mg/cm^2/day), respectively during initial growth phases, viz 45–90 and 90–120 DAP. Similar to planting pattern, NPK levels could not alter the fibre quality.

Besides growth and yield, economic viability in crop management is the foremost criteria in transforming new investigation to the farmer's field. Highest gross returns (₹ 46 000/ha), net return (₹ 22 373/ha) and benefit: cost ratio (1.9) were calculated with planting of *Bt* hybrid at 75 cm × 60 cm spacing (Table 1). This result was mainly due to the enhancement in the seed cotton yield under these combinations. Raghuramireddy *et al.* (2007) recorded higher net returns and net returns/rupee under closer spacing because of higher seed cotton yield. Row spacing of 75 cm × 30 cm recorded significantly higher seed cotton yield and gross returns over that in 90 cm × 45 cm as reported by Anand *et al.* (2008). Amongst nutrient levels, 150% NPK (135:67.5:67.5 kg N, P_2O_5 and K_2O/ha) registered the highest gross return (₹ 45 400/ha), net returns (₹ 21 148/ha) and benefit cost ratio (1.8). However, the economics of nutrient use efficiency (0.74 kg/rupee invested on NPK) and partial factor productivity (10.3 kg/kg NPK) were maximum with 100% NPK. Further increase in fertilizer level led to decrease

Table 2 Effect of planting pattern and NPK levels on climatic variables

Treatment	2003–04	2004–05	2003–04	2004–05	2003–04	2004–05	2003–04	2004–05	2003–04	2004–05
	0–45 DAP		46–90 DAP		91–120 DAP		121–150 DAP		0–150 DAP	
Seed cotton yield (tonnes/ha)									2.4	1.5
Rainfall received (mm)	139	50	212	243	2	36	0	0	352	329
Cumulative solar radiation (cal/cm^2/day)	18 776	18 588	13 884	15 591	12 576	11 744	13 243	12 982	58 480	58 904
Growing degree days (degree days)	553	556	465	483	253	259	270	263	1 541	1 560
Heat units	44 01	4 212	2 099	2 922	1 763	1 675	2 116	2 117	10 380	10 925
Vapour pressure deficit (kPa)	570	601	339	381	326	270	357	321	1 592	1 574
Relative temperature disparity (°C)	438	441	352	370	178	184	195	188	1 163	1 183
Relative humidity disparity (%)	22	22	14	16	17	13	16	16	69	66

Base temperature is 18 °C

in the economic indices, nutrient-use efficiency and partial factor productivity.

Cotton is reported to incur 60% of its total yield losses against normal season due to seasonal variation alone. In the present investigation, crop productivity accrued in terms of seed cotton following altered planting pattern and varied NPK levels was differed with seasonal variables experienced during both the crop years (2003–04 and 2004–05). Favourable climate during 2003–04 resulted in higher yield (2.4 tonnes/ha) relative to the unfavouable year (2004–05, 1.5 tonnes/ha) despite the fact that the same *Bt* hybrid (MECH 162 *Bt*) was repeated following similar management practices in the same field over the seasons (Table 2). It may be due to higher seasonal rainfall received in first 45 days of crop growth (139 mm) during 2003 over 2004 (50 mm) as the former influenced positively towards better crop growth and development that led to realization of higher yield.

Concomitant with the steep increase in adoption and spread of *Bt* technology following its introduction proved the viability of *Bt* technology under Indian condition. Exploitation of suitable agronomy via optimum population and positive input response were essential for realization of higher yield and economic benefits. On the basis of above, it is confirmed that because of compactness in its growth habit favouring higher plant population of 22 200/ha maintained at 75 cm × 60 cm was optimum for realizing higher seed cotton yield. Similarly, crop requirements for NPK in excess of 25–50% could help in realizing higher seed cotton and yields. Impact of seasonal variation did play a critical role in productivity realization even under irrigated conditions.

SUMMARY

A field trial was conducted during two consecutive fall seasons of 2003–04 and 2004–05 to study the effect of three planting patterns and three NPK levels on *Bt* cotton under irrigated situation at semi-arid condition of Coimbatore. Existing planting pattern, viz 90 cm × 60 cm for *Bt* hybrid adopted from the conventional hybrid was below optimum from the stand point of morphology and yield formation. *Bt* hybrids planted at wider spacing produced relatively lesser values in parameters of growth, viz leaf area index and total biomass, and seed cotton yield. Since *Bt* hybrid is compact in its growth habit favouring higher plant population achieved at a spacing of 75 cm × 60 cm was optimum for realizing higher seed cotton yield. Similarly, the existing NPK level recommended for conventional hybrids was not adequate for *Bt* hybrids as evident from lesser growth, lower reproductive counts and decrease in seed cotton yield. Thus, crop requirements for NPK in excess of 25–50% could help in realizing higher dry weights and yields. On economic front, highest gross returns (₹ 46 000/ha), net returns (₹ 22 373/ha) and benefit: cost ratio (1.9) were realized with 75 cm × 60 cm spacing. Application of 150% of NPK (135:67.5:67.5 kg of N, P_2O_5 and K_2O/ha) calculated the highest gross returns (₹ 45 400/ha), net returns (₹ 21 148/ha) and benefit: cost ratio (1.8). Effect of seasonal variation on *Bt* cotton showed that high rainfall received early in the season during 2003–04 influenced positively towards better crop growth and development that led to realization of higher yield.

REFERENCES

Anand S R, Ramesh Babu, Ashoka P and Smitha R. 2008. Studies on yield, economics and bollworm incidence of *Bt* cotton (*Gossypium* spp) hybrids as influenced by different plant spacings. *Crop Research* **36**(1–3): 120–4.

Bhalerao P D, Gawande P P, Ghatol P U and Patil B R. 2008. Performance of *Bt* cotton hybrids for various spacing under rainfed condition. *Agricultural Science Digest* **28**(1): 54–6.

Buttar G S and Singh P. 2006. Performance of *Bt* cotton hybrids at different plant populations in south eastern region of Punjab. *Journal of Cotton Research and Development* **20**(1): 97–8.

Chen Dehua, Ye Guoyou, Yang Changquin, Chen Yuan and Wu Yunkang 2004. Effect after introducing *Bacillus thruingiensis* gene on nitrogen metabolism in cotton. *Field Crop Research* **87**: 235–44.

Jose P H and Cothren J T. 2000. Growth and yield comparison of cotton planted in conventional and ultra-narrow row spacing. *Crop Science* **40**: 430–5.

Mayee C D, Phundan Singh, Punit Mohan and Agarwal D K. 2004. Evaluation of *Bt* transgenic intra- hirsutam hybrids for yield and fibre properties. *Indian Journal of Agricultural Sciences* **74**(1): 746–7.

Nehra P L, Nehara K C and Kumawat P D. 2004. Performance of *Bt* cotton hybrids at different spacings in canal command area of north-western Rajasthan. *Journal of Cotton Research and Development* **18**(2): 189–90.

Perumal N K 1999. Effect of different nitrogen level on morpho-physiological characters and yield in rainfed cotton. *Indian Journal of Plant Physiology* **4**(1): 65–7.

Puri S N, Murthy K S and Sharma O P. 1999. Integrated pest management affordable basis and compatible tactics. *Proceedings of Seminar on Integrated Pest Management*, pp 19–31. Indian Crop Protection Association, New Delhi.

Raghuramieddy P, Gopinath M and Jalapathirao L. 2007. Performance of genetically modified cotton at different fertility levels and plant geometry under irrigated condition. *Crop Research* **34** (1–3): 305–7.

Rekha G O. 2007. A comparative assessment of morpho physiolgical characters and yield in *Bt* and non-*Bt* Cotton hybrids. *Karnataka Journal of Agricultural Sciences* **20**(4): 901.

Singh Jagvir and Rao M R K. 2002. Agronomical evaluation of *Bt* Rasi hybrid cotton in rainfed Vertisol. *Annual Report*, pp 44. Central Institute for Cotton Research, Nagpur.

Venugopal K. 2004. Changing paradigms (avenues/approaches) in cotton production technologies for improving productivity and fiber quality of cotton. (*in*) *Proceedings of the International Symposium on Strategies for Sustainable Cotton Production-A Global Vision*, pp 1–6. *Crop Production* Vol. **2**, 23–25 November 2004, UAS, Dharwad.

Vishwanath 2007. Response of late sown *Bt* cotton (*Gossypium hirsutum* L.) to plant spacings, fertilizer levels and NAA applications under irrigation. *Karnataka Journal of Agricultural Sciences* **20**(4): 899.