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Performance of *Bt* cotton (*Gossypium hirsutum*) hybrid on shrink-swell soils of central India*

V RAMAMURTHY[1] and M V VENUGOPALAN[2]

National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra 440 010

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Cotton (*Gossypium hirsutum* L.), an important commercial crop of shrink-swell soils (Vertisols and associated soils) is cultivated with intensive use of pesticides. Among the various pests of cotton, the American bollworm (*Helicoverpa armigera Hubner*) is of major concern to the cotton farmer. Initial Participatory Rural Appraisal (PRA) exercises during 2003 identified poor crop yield and high cost of production due to heavy incidence of sucking pests and bollworms and non-availability of resistant hybrids to bollworm in cotton as serious constraints. During the process, farmers were also able to identify opportunities to circumvent these problems by growing *Bt* cotton hybrids possessing resistance to bollworms.

Introduction of *Bt* gene in cotton and subsequent adoption of the resultant *Bt* cotton has increased the productivity of the crop not only in the developed countries but also in some of the developing countries (Hallikere *et al*. 2004 and Bhatade *et al*. 2006). This technology received overwhelming response in India (ICAC 2008). The Genetic Engineering Approval Committee (GEAC) initially approved 3 *Bt* cotton hybrids ('MECH 162', 'MECH 184' and 'MECH 12') for commercial cultivation in Maharashtra during 2002 (Barwale *et al.* 2004). Bt cotton trials conducted on-station in India have indicated greater yield potential of *Bt* as compared to non-*Bt* hybrids. This study focuses on the on-farm participatory evaluation of *Bt* cotton 'MECH 184' as it was more promising than other two *Bt* hybrids against the locally popular hybrid 'NHH 44' for its potentiality, quality and economics on different soils.

The study was carried out in farmers' fields during the *kharif* (monsoon) season of 2003–04 and 2004–05 in Kokarda and Kaniyadol watershed (21° 20' N Latitude and 78° 51' E Longitude) of Nagpur district, Maharashtra.

Agro-climatically, the experimental sites are located in the eastern Maharashtra plateau experiencing hot, dry, sub-humid climate, characteristic of the agro-eco sub-region 10.2 and are dominated by Vertisols (deep black soils) and associated soils. Moderate deep-to-deep soils are found in valley, while shallow to medium deep soils are on escarpments. The shallow soils are severely degraded, whereas deep soils have drainage problem. On-farm trials were conducted in medium deep (depth up to 66 cm with 53.3% clay, 0.62% organic carbon (OC), 11.8% $CaCO_3$ and 8.2 *p*H), deep (depth up to 80 cm with 55.3% clay, 0.69% OC, 10.9% $CaCO_3$ and 8.3 *p*H) and very deep (depth up to 150 cm with 61.7% clay, 0.49% OC, 10.9% $CaCO_3$ and 8.3 *p*H) soils, which are suitable for cotton. The region receives an average annual rainfall of around 960 mm and about 95% of this received during cotton-growing season. However during the cropping season of 2003–04 the rainfall during the cotton growing season was 14% more than the normal, whereas 2004–05 was a drought year and the region received 34% less than normal. Rainfall is received mostly from south-west monsoon from second week of June continues up to October. The maximum rainfall received in July. Rainfall covers only 77% of the gross annual water demand, even in normal rainfall year.

In all 15 farmers were selected with 0.40 ha area each to test the *Bt* cotton 'MECH 184' along with a non-*Bt* locally popular intra-hirsutum hybrid of the region 'NHH 44'. The evaluation was done on the three soil types, viz Typic Haplustepts, Vertic Haplustepts and Typic Haplusterts. Thus, there were five farmers on each soil type, which served as replications. The sowing was done with the onset of monsoon. As per recommendations, 100 kg N: 50 kg P: 50 kg K/ha was applied in split doses, 50% of N and 100% of P and K was applied after emergence of seedling as basal and remaining N was applied after 50 days after sowing. Only four insecticide sprays were required to protect *Bt* cotton

*Short Note

[1]Senior Scientist (Agronomy) (e mail: ramamurthy20464 @yahoo.co.in), NBSS&LUP, Regional Centre, Hebbal, Bengaluru 560 024;

[2]Principal Scientist (Agronomy) (e mail: mvvenugopalan @rediffmail.com), CICR, Nagpur, Maharashtra

crop from sucking pests and 10 and 6 insecticides sprays were applied to 'NHH 44' to protect from sucking pest and bollworm during 2003–04 and 2004–05 respectively. Observations on growth and yield parameters (number of bolls/plant and boll weight) were recorded at harvesting. Quality parameters, like fibre length, uniformity index, fineness and bundle strength of *Bt* cotton and 'NHH 44' were tested from first picking. The incidence of bollworms was higher in 2003–04 than in 2004–05 warranting six additional sprays in 2003–04 in 'NHH 44' as compared to only two in 2004–05 (no spray was needed to control bollworms in 'MECH 184'). However, the incidence did not build-up to epidemic proportion as experienced in the recent past.

The average cost of seed/ha was Rs 4 000 for 'MECH 184' and Rs 650 for 'NHH 44'. The plant protection cost was Rs 3 000/ha in both the years in 'MECH 184' compared to Rs 5 750 for 'NHH 44' in 2003–04 (a year of relatively high bollworm incidence) and Rs 4 880 in 2004–05. The information on cost of seed, cost of spraying, productivity, market price (Rs 2 000/100 kg) and opinion of farmers were collected for both 'MECH 184' and 'NHH 44' cotton in both seasons. The seed cotton yield was statistically analyzed by using a split-plot design with soils as the main plots and hybrids as sub-plots.

Farm walks and semi-structural focus group discussions were used to facilitate evaluation of the trials by the farmers themselves and this concluded with a formal matrix ranking exercise. In these, farmers were asked to make decisions on the merits and demerits of *Bt* cotton over the conventional hybrid in a number of researcher defined, but mutually agreed, categories relating to pest management, pesticide sprays, agronomy, crop development and yield.

Seed cotton yield of 'MECH 184' was significantly higher than 'NHH 44' in both the years by 11 and 31% in 2003–04 and 2004–05, respectively (Table 1). Bolls retained in 'MECH 184' were heavier than 'NHH 44' and contributed to the significantly higher yields (Table 2). Averaged over hybrids, productivity was 79% higher in 2003–04 than 2004–05. Rainfall amounts and distribution were nearly normal in 2003–04, but were low and erratic in the 2004–05. Only 58.1 mm rainfall was received after August in 2004 (as against 229 mm in 2003–04) probably resulting in severe soil-moisture stress during boll development phase.

Total dry matter production, number of bolls/plant and boll weight was also higher in 2003–04 compared to 2004–05, (Table 2). Both boll number and boll weight were significantly higher in 'MECH 184' than 'NHH 44' in 2004–05, whereas the difference in boll number was not significant in 2003–04. The dry matter production was also significantly higher in 'MECH 184'. This increase over 'NHH 44' was 17.1% in 2003–04 and 21.4% in 2004–05.

Since 'MECH 184' is a comparatively short-duration hybrid with synchronized flowering habit, matured earlier than 'NHH 44', it escaped severe soil moisture deficit experienced during November and December 2004 and on an average the crop was harvested in 140 days after sowing compared to 160 DAS in 'NHH 44'.

Thus, it is evident that both in a year of moderate pest incidence (2003–04) as well as drought year (2004), *Bt* cotton hybrid 'MECH 184' was superior to 'NHH 44'. Similarly Bhatade *et al.* (2006) tested *Bt* (MECH 162) along with non-*Bt* cultivars through on-farm trails in different locations of Marathwada region of India under varying soil and rainfall conditions and observed the superiority of *Bt* cotton in most of the cases.

Soil effect on seed cotton yield was significant only in 2003–04. Growing of cotton on Typic Haplusterts was significantly superior than Vertic Haplustepts and Typic Haplustepts (Table 1). Further, Vertic Haplustepts produced significantly higher seed cotton yield than Typic Haplustepts. Similarly, the number of bolls/plant and boll weight was significantly influenced by soil type in 2003–04 (Table 2). Typic Haplusterts recorded significantly higher number of bolls (32.0/plant) and boll weight (4.7g/boll) compared to other soils. The effect of soil on performance of hybrids was significant only in the normal year (2003) in which deep and very deep soils support a better cotton crop than medium deep soils. Among the soils, Typic Haplusterts were significantly superior to Vertic and Typic Haplustepts. This may be because of better water-holding capacity of these soils (Blaise *et al*. 2005).

Total dry matter production at 120 days after sowing was

Table 1 Seed cotton yield (kg/ha) as influenced by soils and hybrids

	2003–04			2004–05		
	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean
Typic Haplustepts	1 773	1 643	1 708	1 103	800	951
Vertic Haplustepts	1 913	1 697	1 805	1 167	877	1 022
Typic Haplusterts	1 997	1 777	1 887	1 163	947	1 055
Mean	1 894	1 706		1 144	874	
		CD (P=0.05)			CD (P=0.05)	
Hybrids		47			86	
Soils		39			NS	
Hybrids × soils		NS			NS	

Table 2 Total dry matter production, number of bolls/plant and boll weight as influenced by soils and hybrids

	Total dry matter production (g/plant) at 120 DAS*						Bolls/plant						Boll weight (g)**					
	2003–04			2004–05			2003–04			2004–05			2003–04			2004–05		
	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean	'MECH 184'	'NHH 44'	Mean
Typic Haplustepts	470.0	440.0	455.0	450.0	400.0	425.0	26.0	20.0	23.0	18.0	15.0	16.5	4.40	3.80	4.10	4.00	3.70	3.85
Vertic Haplustepts	560.0	460.0	510.0	520.0	415.0	467.0	30.0	25.0	27.5	20.0	15.0	17.5	5.10	4.00	4.55	4.50	3.80	4.15
Typic Haplusterts	575.0	470.0	522.5	560.0	445.0	502.0	34.0	30.0	32.0	22.0	18.0	20.0	5.20	4.20	4.70	4.40	3.90	4.15
Mean	535.0	456.7		510.0	420.0		30.0	25.0		20.0	16.0		4.90	4.00		4.30	3.80	
	CD (P=0.05)			CD (P=0.05)			CD (P=0.05)			CD (P=0.05)			CD (P=0.05)			CD (P=0.05)		
Hybrids	10.4			12.0			NS			2.7			0.21			0.25		
Soils	12.7			14.6			6.2			NS			0.25			NS		
Hybrids × soils	17.9			20.7			NS			NS			NS			NS		

* DAS days after sowing
** First picking boll weight

significantly affected by soil types in both the years. Typic Haplusterts recorded significantly higher total dry matter production (522.5 and 502 g/plant in 2003–04 and 2004–05 respectively) compared to Vertic Haplustepts and Typic Haplustepts (Table 2).

The interaction between soil type and hybrid for dry matter production was significant in both the years. *Bt* cotton 'MECH 184' grown on Typic Haplusterts produced significantly higher total dry matter production than all other treatments (Table 2).

'MECH 184' had improved fibre length (30.4 and 30.1 mm in 2003–04 and 2004–05 respectively), bundle strength (24.2 and 22.1 g/text in 2003–04 and 2004–05 respectively) and uniformity ratio (52 and 54 in 2003–04 and 2004–05) than 'NHH 44' (27.4 and 26.2 mm fibre length, 20.2 and 19.2 g/text bundle strength and 51 and 52 uniformity ratio in 2003–04 and 2004–05 respectively). 'NHH 44' recorded higher micronaire value (4.3 and 3.8 in 2003–04 and 2004–05 respectively) compared to 3.6 and 3.4 recorded in 'MECH 184'. The values were lower in 2004–05 than 2003–04. Drought condition reduced length, strength and maturity (micrnaire value) but increased uniformity ratio. The superiority of 'MECH 184' over 'NHH 44' in terms of fibre quality parameters observed in this study is similar to those reported by Hallikeri *et al.* (2004).

The average cost of seeds/ha was Rs 4 000 in 'MECH 184' and Rs 650 in 'NHH 44'. The plant protection cost was Rs 3 000/ha in both the years in 'MECH 184' as against Rs 5 750 for 'NHH 44' in 2003–04 (a year of relatively high bollworm incidence) and Rs 4 880 in 2004–05. With 'MECH 184', the net returns were higher (than 'NHH 44') by Rs 3 200/ha in 2003–04 and Rs 3 900/ha in 2004–05. The cost:benefit ratio was slightly higher in case of 'MECH 184' (4.4 and 2.26) compared to 'NHH 44' (4.3 and 2.16). With the reduction in cost of seed from Rs 1 400/450 g in 2003–04 and 2004–05 to Rs 750/450 g of seed in 2007, the cost of seed has reduced nearly 50% and proportionately the profitability of *Bt* cotton net returns and cost : benefit ratio also increases. Reduction in cost of seed is mainly due to increased adoption of *Bt* cotton, which facilitated seed production on a commercial scale.

Opinion of the farmers was collected regarding the performance of *Bt* cotton hybrid on certain important aspects of growth, yield and quality. Majority of the farmers who participated in on-farm evaluation felt that 'MECH 184' is resistant to bollworms, possessed good fibre quality and gave higher yield than 'NHH 44'. Farmers also felt that 'MECH 184' had a comparatively lower boll drop (70%), more drought resistance (70%), easier detachment from locules (80%), determinate in growth (80%), lower flower drop (60%) and higher boll size (50%) than 'NHH 44'. High scores were also reported for 'MECH 184' with respect to reddening of leaf and planting of refugee rows of non-*Bt* cotton, which, the farmers felt was a cumbersome process. However, despite

these demerits an overwhelming number (70%) of participating farmers want to adopt *Bt* hybrid in future because of its shorter duration, which provided an opportunity (wherever late season rains or supplemental irrigation is available) to take a winter crop of wheat or gram after cotton.

'MECH 184' performed better than 'NHH 44' on Vertisols and associated soils with respect to higher seed cotton yield, net return and cost: benefit. The yield was higher in a year of increased bollworm incidence (2003–04) owing to its in-built resistance to bollworm as well as in a drought year (2004) because of its earliness. These twin merits has motivated farmers to adopt *Bt* cotton despite a higher seed cost. Moreover, cultivation of *Bt* cotton 'MECH 184' also gave greater opportunity for timely sowing of the succeeding crop.

SUMMARY

Transgenic *Bt* Cotton hybrid 'MECH 184' (*Gossypium hirsutum* L.) was compared with the hybrid 'NHH 44' on farmers' fields in Kokarda and Kaniyadol watershed of Nagpur district, Maharashtra, India during rainy season (*kharif)* 2003–04 and 2004–05. 'MECH 184' gave significantly higher seed cotton yield (17%) than the conventional hybrid 'NHH 44'. The performance of the hybrid significantly varied in different soils in 2003–04 where significantly higher seed cotton yields were recorded on Typic Haplusterts (1 887 kg/ha) compared to Vertic Haplustepts (1 805 kg/ha) and Typic Haplustepts (1 708 kg/ha). The net profit and cost : benefit ratio obtained by growing 'MECH 184' was slightly higher (Rs 23 300/ha and 3.33, respectively) than that of 'NHH 44'. Farmers' preferred to adopt *Bt* cotton even though the initial seed cost was higher than conventional hybrids because of reduced plant protection cost and shorter duration, which in turn facilitates timely sowing of the subsequent wheat or gram wherever some winter rainfall is received or supplementary irrigation is available.

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