Performance of Genetically Transformed Bt Cotton in South Africa and Implications for Emerging Small Scale Farmers

A.L. Bennett
Monsanto South Africa Pty (Ltd)P.O. Box 78025, Sandton, 2146, South Africa

ABSTRACT

The Delta and Pinelands cotton cultivars, NuCOTN 37B and NuCOTN 35B, containing Monsanto's patented Bollgard® Bt-gene technology was performance tested under irrigated, rainfed and small scale conditions in all cotton producing regions of South Africa (approximately 25 trials). A minimum of 1ha of the transgenic cultivar was planted adjacent to its non-transgenic parent, and the co-operating farmer managed each cultivar as an extension of his own cotton. The only exception was with respect to insect control. The non-transgenic block was sprayed according to the farmers own system, while the Bollgard block was only sprayed when a threshold of 5 larvae per 24 plants was equalled or exceeded. Each block was assessed for larvae of Helicoverpa armigera, Diparopsis castanea and Earias spp. at weekly intervals. Presented results summarize the larval infestations on each of the cultivars, the number of sprays on each of the cultivars as well as the yields and fiber qualities. Under both irrigated and rainfed production, the larval threshold was regularly exceeded in non-transgenic blocks, whereas it was very rarely exceeded in transgenic blocks (only once in three of the trials). Under commercial irrigated conditions the reduction in the number of sprays varied between 4 and 7, whereas under commercial dryland conditions the saving varied between 4-6. Under small-scale production (dryland), one producer saved 9 sprays. In general the transgenic cultivars out-yielded their non-transgenic parents by 5-20%. The implications of genetically modified Bt cotton for emerging small scale farmers in Africa is also discussed. The main advantages are huge labour and timesaving as well as increased yields. Technology of this nature should make a significant contribution to cotton production in Africa.

Introduction

The biological insecticide *Bacillus thuringiensis* (Berliner) has been used for upwards of 50 years to control lepidopteran pests in a variety of crops (Dubois and Lewis, 1981). More recently, Monsanto has developed and introduced a new method to control lepidopteran larvae in cotton, by adding a gene derived from *B. thuringiensis kurstaki* (*B.t.k.*) to the cotton genome (Perlak *et al.*, 1990). This larvae-resistant or Bollgard gene produces the Cry1A(c) protein that proves fatal when ingested by certain lepidopteran larvae. (Bollgard® is a registered trade name belonging to Monsanto Life Sciences Company, St Louis, Missouri). Cotton producing this protein has been registered as a plant pesticide with the EPA (EPA Reg. No. 524-478) and was commercialized in the USA in 1996. The Cry1A(c) protein produced by the Bollgard gene is virtually identical to that produced in nature and by commercial formulations of *Bacillus thuringiensis* that are registered in South Africa for use against bollworms in cotton. This protein has a narrow range of activity against lepidopteran larvae and consequently beneficial insects are unaffected. When this advantage is coupled with the fact that cotton expressing Cry1A(c) will require fewer applications of conventional insecticides, the benefit to the environment becomes apparent.

Several authors have shown that both interspecific and intraspecific variation in the susceptibility of lepidopteran larvae to *B.t.k.* delta-endotoxins occur. Kinsinger and McGaughey (1979) reported a 42-fold difference in LC_{50}'s among *Plodia interpunctella* (Hübner) populations. Stone and Sims (1993) found that the range in LC_{50}'s among populations in response to purified *B.t.k.* endotoxin was 8-fold for *Heliothis virescens* (F.) and 16-fold for *Helicoverpa zea* (Boddie).

This paper reports the results of a series Bollgard performance tests conducted in South Africa aimed at determining the efficacy of genetically modified Bollgard cotton in providing resistance to *Helicoverpa armigera* (Hübner), the American bollworm, *Diparopsis castanea* Hampson, the Red bollworm, and *Earias insulana* (Boisduval) and *Earias biplaga* Walker (Spiny bollworms). The transgenic cotton varieties used in these tests was NuCOTN 37B and NuCOTN 35B (Both NuCOTN 37B and NuCOTN 35B are cotton variety names registered to Delta and Pinelands Company, Scott, MS. USA).

Materials and methods

Co-operating cotton producers from each of the major South African cotton regions were given sufficient seed to plant at least 1 ha of Bollgard cotton and 1 ha of the corresponding, non-transgenic cotton parent variety. Many of the co-operators also planted an adjacent block of the variety best suited to their particular region. In this way some 25 trials were planted under irrigation, rainfed or small scale cultivation practices. The irrigation trials were situated in the northern Cape (Jan Kempdorp and Upington), Mpumalanga and Northern Provinces. Rainfed trials were situated predominantly in the Northern Province and Kwazulu-Natal, while small-scale farmer trials were only in Kwazulu-Natal.

All trials were planted according to local cultivation practices, generally resulting in plant populations of 70-80K plants/ha for irrigation, 30-40K plants/ha for rainfed and about 50-60K plants/ha under small scale conditions.

Trials were scouted (20 plants/block) on a weekly basis from 6-8 weeks after emergence until 16-18 weeks after emergence. In all trials the numbers of larvae of *H. armigera, D. castanea* and *Earias* spp. were recorded. In some additional trials the larval instar was also recorded. The Bollgard blocks were sprayed for bollworms only when a local threshold equivalent of 5 larvae/24 plants was equalled or exceeded. Non-transgenic blocks were sprayed for bollworm according to the farmer's commercial practice. At the end of the season, trails were assessed for yield and the numbers of sprays put down on transgenic and non-transgenic blocks compared using t-tests.

Results

Egg and larval counts

Over 16 trials analyzed, the mean total number of eggs recovered from transgenic cotton over the period of assessment did not differ significantly ($p>0.05$) from those recovered from the non-transgenic parents (Table 1). This indicates that although there were slightly fewer eggs recovered from the transgenic cotton, there was no oviposition preference evident. In contrast there was a very significant ($p<0.01$) difference in the mean total number of larvae recovered from transgenic cotton compared with the number of larvae recovered from insecticide treated, non-transgenic cotton (Table 1). The mean total number of bollworms recovered from transgenic cotton over the whole period of assessment was 4.4 compared with 31.5 for the treated, non-transgenic cotton.

Numbers of sprays

The mean overall number of bollworm sprays saved (data from 19 trials) by using Bollgard cotton was highly significant (4.68, $p<0.01$)(Table 2). Under commercial dryland conditions the saving was 3.8 sprays, under commercial irrigated cotton 5.1, and for small scale farmers 5.8.

Yield

The mean yield increase of Bollgard over the non-transgenic variety was significant ($p<0.05$). Under commercial dryland conditions there was a 23 % increase (264 kg/ha), under commercial irrigated conditions the increase was 23% (868 kg/ha) and for small scale farmers the increase was 33.3% (463 kg/ha).

Discussion

It is clear that Bollgard provides both the commercial and small scale cotton grower with an exceptionally efficient means of controlling bollworms in South African cotton. While it is obvious that commercial growers will derive considerable benefits from this technology, transgenic Bt-cotton is likely to have the greatest impact on small scale producers. The main advantages for emerging growers are essentially two-fold. Insecticides are generally applied by knapsack sprayer. There are 10 000 m of row cotton in a hectare, which means a grower has to walk at least 20 km to spray one hectare. A saving of 5.8 sprays per season saves the grower at least 115 km walking per hectare per season. This saving in both time and labour will make it possible for small scale growers to manage more cotton, thereby increasing the scale of operation. Additional benefits include a reduction in the handling of dangerous chemicals. The second benefit is the improved level of bollworm control resulting in significantly higher yields. For small-scale production this represents a much better utilization of land, which in many cases is a limited resource. In Africa, where cotton represents an important cash crop for the majority of small scale growers, and since most of Africa's cotton is produced by small scale farmers, Bollgard has the potential to significantly improve the quality of life of a great many people.

References

Kinsinger, R.A. and W.H. McGaughey. (1979): Susceptibility of populations of Indianmeal moth and almond moth to *Bacillus thuringiensis*. J.Econ. Ent. 72:346-349.

Stone, T.B. and S.R. Sims. (1993): Geographic susceptibility of *Heliothis virescens* and *Helicoverpa zea* (Lepidoptera: Noctuidae) to *Bacillus thuringiensis*. J. Econ. Ent. 86:989-994.

Table 1. Comparison of total egg and bollworm numbers between Bollgard and non-transgenic cultivars, over 16 trials.

	Mean total bollworm eggs/block			Mean total bollworm larvae/block		
	Bollgard	non-transgenic	Difference	Bollgard	non-transgenic	Difference
Mean	33.19	42.94	9.75	4.44	31.50	27.06
t Stat			1.76ns			9.86**

**p<0.01

Table 2. Comparison of numbers of bollworm sprays between Bollgard and non-transgenic cultivars over 19 trials.

	Bollgard	non-transgenic	Difference
Mean	0.32	5.00	4.68
t Stat			14.42**

** p<0.01

Table 3. Comparison of mean yields (kg/ha) of Bollgard and non-transgenic cultivars (total of 24 trials).

Production	Mean yield (kg/ha)		Difference
	Bollgard	non-transgenic	
Com. dryland	1429.9	1166.0	263.9*
Com. irrigated	5010.7	4142.2	868.5*
Small scale.	1934.7	1451.0	483.7*

*: p<0.05