Do sowing rules change for high fruit retention transgenic cotton?

Michael Bange[1] and Rose Roche

CSIRO Division of Plant Industry, Cotton Catchment Communities Cooperative Research Centre, Locked Bag 59, Narrabri, NSW 2390 Email Michael.Bange@csiro.au rose.roche@csiro.au

Abstract

Recently, genetically engineered (transgenic) varieties of cotton expressing genes from *Bacillus thuringiensis* (Bt) have been made available to cotton growers throughout the world. In Australia cotton growers have access to Bt cotton that contains genes that express the insecticidal proteins Cry1Ac and Cry2Ab (Bollgard II?). Bollgard II offers significant potential to reduce pesticide use to control major Lepidopteran pests (particularly *Helicoverpa spp*. in Australia). As a consequence of reduced insect damage, retention of squares (flower buds) and young bolls can be higher in Bollgard II cultivars than non-Bollgard II (non-Bt) cultivars. There is a concern that later growth and fruiting of Bollgard II may be limited by the greater demands for photoassimilate from improved early fruit retention, reducing the yield potential of the crop. To address this, changes in sowing date and plant population were examined in Bollgard and non-Bollgard varieties. Delayed sowing in Bollgard II may increase canopy size to meet earlier and higher boll demand, or increasing plant density beyond the recommended values (8 to 12 plants m^{-2}) may compensate for smaller plants caused by higher fruit retention of Bollgard II. The results suggested there is an opportunity to delay sowing date and maintain yield of Bollgard II, but there was no evidence that plant population recommendations need to change when compared to non-Bollgard II cultivars.

Key Words

Cotton, Bollgard II, sowing-date, plant population

Introduction

Australian cotton growers now have access to cotton cultivars that contain genes that express insecticidal proteins taken genes from *Bacillus thuringiensis* (Bt) (Bollgard II?, Monsanto). Bollgard II cotton reduces the need to use chemical pesticides to control *Helicoverpa spp*., that feed preferentially on young growing tips or reproductive structures of cotton plants (Fitt, 2000). As a consequence of the improved insect control and the reduced use of chemical pesticides conserving beneficial insect activity, the retention of squares (flower buds) and young bolls (fruit) is improved resulting in earlier and overall higher fruit retention of Bollgard II cultivars (Wilson et al. 2004).

As cotton is an indeterminate species, the timing of crop maturity is largely determined by the capacity of the plant to continue the production of new fruiting sites. Cessation of fruit production (‘cut-out’) occurs when the demand on the resource supply by growing fruit increases to a point where none remains for the initiation and support of new fruiting sites (Hearn 1972). A limitation may occur with high fruit retention crops if the demands of high early fruit load (due to the high retention) reduce resources available for continued growth and fruiting (Hearn 1994) leading to smaller plants, earlier cut-out and lower yield (Bange and Milroy 2004). When compared to non-Bollgard II cotton, Bollgard II may have less capacity for resource capture (light interception) to support fruit growth resulting in earlier cut-out and less fruit growth per plant.

To overcome this potential problem, two approaches have been suggested. First, sowing Bollgard II cultivars should be delayed by up to a month. The warmer conditions associated with this would increase canopy size, which would help meet the greater demand from the higher earlier fruit load. Second, plant density should be increased beyond the recommended number of 8 to 12 plants m^{-2}. The higher plant population would compensate for the smaller plants that may result from higher fruit retention of Bollgard II. A lack of definitive evidence for how the technology affects the growth of the plant, has meant that management practices, including sowing date and planting density, are being revisited in Australia. Four field experiments (two sowing date, two plant density) compared the yield performance of Bollgard II with non-Bollgard equivalent cultivars.

Methods

Cultural details

All field experiments were conducted at Narrabri (30.13?S 149.78?E) with full irrigation using non-limiting rates of nitrogen. Treatment plots contained 8 rows (2 buffer rows each side) spaced at 1m. All experiments compared two cultivars, Bollgard and non-Bollgard in a factorial arrangement with either time of sowing or plant density (Table 1). The two sowing date experiments consisted of three times of sowing, while the plant density experiments had four established plant densities. All the experiments were designed as randomised complete blocks with 3 or 4 replicates. . Insect control was based on the needs of the non-Bollgard II cultivar to ensure a bias in the control of *Helicoverpa spp*. towards the Bollgard II cultivars (May et al. 2003) that may lead to them having higher fruit retention. Lint yield in the sowing date experiments was estimated from a 1 m^2 handpicked harvest in each plot while in the density experiments lint yield was measured using a spindle picker plot harvester from 8 m^2. Final total fruit retention was measured on 1 m^2 in each plot when 100% of bolls were open. Fruit retention is expressed as the percentage of open bolls relative to the number of total fruiting sites present. Analyses of variance and regression analyses were conducted using Genstat? and Sigma Plot? software respectively.

Table 1. Summary of experiment details of sowing date and plant density experiments. For cultivars B denotes cultivars that contain the Bollgard II? genes; R and RR denotes cultivars that contain only the Roundup Ready? gene; and BR are cultivars that contain both Bollgard II? and Roundup Ready? genes[A].

Experiment	Sowing Date	Bollgard II Cultivar	Non-Bollgard II Cultivar	Plant Density (plant m^{-2})	Plot Size	Reps.
Sowing date Exp.1	13/10/03 (S1) 5/11/03 (S2) 28/11/03 (S3)	Sicot 289BR	Sicot 189R	11.0	8 m x 18 m	4
Sowing date Exp.2	6/10/04 (S1) 22/10/04 (S2) 4/11/04 (S3)	Sicot 289BR	Sicot 189R	13.5	8 m x 18 m	3
Plant Density Exp. 1	25/10/05	Sicot 71BR	Sicot 71RR	4.4, 8.3, 10.5, 14.1	8 m x 12 m	4
Plant Density Exp. 2	18/10/06	Sicot 71BR	Sicot 71RR	5.2, 8.1, 12.2, 16.4	8 m x 12 m	4

[A]Bollgard II? and Roundup Ready? are registered trade names of the Monsanto company.

Results

Fruit Retention

In the sowing date experiments there was no significant interaction of sowing date and cultivar, however final total fruit retention was significantly less for the non-Bollgard II cultivar in each experiment (Table 2). Differences across sowing dates were only significant in Exp. 1 where retention declined with later sowing (S1 = 53.8%, S2 = 46.1%, S3 = 38.1%). There was no significant interaction of cultivar and plant density on fruit retention. Bollgard II had higher total fruit retention in both experiments but was only significantly higher in Exp. 1 (15.1% greater) (Table 2). Total fruit retention was unaffected by plant density.

Yield

Yields were consistently lower for the non-Bollgard II cultivar with later sowing dates in both experiments, while yield only substantially declined for the Bollgard II with the much later sowing in Exp. 2. Pooling data across all experiments showed that the relationship between yield and sowing date differed significantly between the Bollgard II and non-Bollgard II cultivars (Fig. 1a). Yield of the non-Bollgard II cultivar declined linearly with later sowing dates (r^2 = 0.85) while Bollgard II yields followed a quadratic response with sowing date (r^2 =0.52).

Pooling yield data across both plant density experiments showed that there were no significant relationships between relative yield (average treatment yield divided by the maximum yield for cultivar in that experiment) and plant density (Fig. 1b) for both Bollgard and non-Bollgard II cultivars.

Table 2. Final total plant fruit retention for sowing date experiments.

Treatment	% Retention Exp.1		% Retention Exp. 2	
	Bollgard II	Non-Bollgard II	Bollgard II	Non-Bollgard II
Sowing 1	55.7	52.0	40.7	32.6
Sowing 2	53.8	38.4	41.3	35.5
Sowing 3	40.1	36.0	42.1	35.1
Cultivar mean	49.9	42.1	41.4	34.4
LSD Cultivar		5.2**		3.7**
LSD Sowing		6.4**		4.5
LSD Sowing x Cultivar		9.0		6.4

**P < 0.01

Table 3. Final total plant fruit retention for plant density experiments.

% Retention Exp. 1			% Retention Exp. 2		
Treatment	Bollgard II	Non- Bollgard II	Treatment	Bollgard II	Non- Bollgard II
Density (4.4)[A]	45.0	31.9	Density (5.2)	44.3	41.9
Density (8.3)	43.6	29.5	Density (8.1)	45.5	37.7
Density (10.5)	42.5	27.2	Density (12.2)	40.5	37.3
Density (14.1)	42.8	24.8	Density (16.4)	37.9	35.2
Cultivar Mean	43.5	28.4	Cultivar Mean	42.0	38.0
LSD Cultivar		2.8**			5.8
LSD Density		4.0			8.2
LSD Cultivar x Density		5.6			11.6

[A] Plant density (plants m^{-2}), $**P < 0.01$

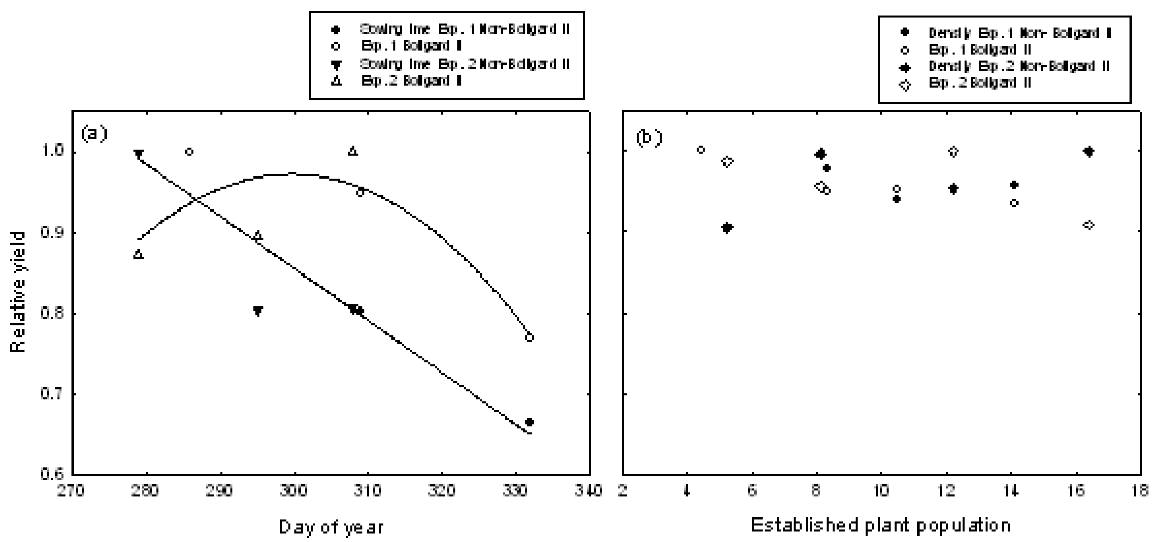

Figure 1. Relative yield (average treatment yield divided by the maximum yield for cultivar in that experiment) for the (a) sowing date and (b) plant density experiments for both Bollgard (open symbols)and non-Bollgard II (closed symbols) cultivars.

Discussion

As expected, fruit retention in Bollgard II cultivars was greater than in the non-Bollgard II cultivars across all experiments but there was no evidence that this limited yield with early sowing dates and changes in plant density. There was however, a difference in the response of Bollgard II to sowing date. The yield of the non-Bollgard II cultivar declined linearly with sowing dates later than mid-late October which is consistent with previous reports of responses to sowing time in non-Bollgard cultivars (Constable et al. 1976). In contrast, the Bollgard II cultivar maintained high yields until an early December sowing before declining. This is most likely due to the higher season-long fruit retention of Bollgard II across all sowings, leading to a shorter fruiting cycle (first flower to maturity). This means that the reduced time between flowering and the end of the potential growing season that resulted from later sowing would have had less impact on the capacity of the crop to complete its fruiting cycle and mature the same number of bolls as at normal sowing dates. The non-Bollgard II cultivar, with lower season-long fruit retention across all sowings, required more time to set and mature its fruit load. The later sowings therefore provided less opportunity to develop fruit numbers similar to the earlier sowings because there was insufficient season length remaining after first flower (Constable et al. 1976). The stability of the cotton yield response to plant density was similar those studies for non-transgenic cotton (Constable 1997). Others who have grown Bt transgenic cotton have also demonstrated the same ability of Bt transgenic cotton to adapt and produce similar yields across a broad range of plant densities (Bednarz et al. 2005, Dong et al. 2006). The concern that the yield potential for Bollgard II was limited at the recommended plant density (8 to 12 plants m^{-2}) and at lower plant densities because of higher and earlier fruit retention was not supported in these studies. Although leaf area of individual plants was not measured in this study, there were no differences in resource capture (intercepted PAR) as a result of the differences in retention between the Bollgard II and non-Bollgard II cultivars across plant densities (data not shown).

There was also no indication in this study of higher fruit retention in Bollgard II in these studies affecting yield. Very high fruit retention has been reported to reduce yield even in non-Bollgard II crops (Gibb 1999, Wilson et al. 2003). This limitation may occur if the demands of high early fruit load (due to the high retention) reduce resources available for continued growth and fruiting (Hearn 1994). Situations where extremely high levels of fruit retention occur will also need investigation. However, in Australia, significant early fruit losses as a result of sucking pests are reducing the likelihood of very high retention in Bollgard II crops occurring (Wilson et al. 2004). It may become necessary to assess other crop management approaches to manipulate crop growth to offset the potential effects of high retention. Early and vigorous crop growth through precise irrigation, nutrient, physical and genetic manipulation of crop architecture, are examples of approaches currently being researched.

Conclusion

As there were differences in Bollgard II compared with non-Bollgard II cultivars across sowing dates, recommendations for optimal sowing dates for different cotton production regions may need to be re-examined. Modifying sowing date for Bollgard II may offer opportunities for Australian growers to help optimise yield and reduce risks associated with poor crop establishment from seedling diseases when crops are sown early when cool conditions prevail. These studies showed no reason to revise recommended plant densities for Bollgard II cultivars in Australia.

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