IMPACT OF ROW CONFIGURATION ON HIGH FRUIT RETENTION (TRANSGENIC) CULTIVARS IN HIGH-YIELDING, HIGH-INPUT COTTON SYSTEMS IN AUSTRALIA

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Abstract

Ultra-narrow row cotton (UNR - rows spaced less than 40 cm apart) has long been seen as a potential alternative system to 100 cm row systems. In Australia, the perceived benefits include improved yield and earlier crop maturity, which are especially beneficial in shorter growing season areas. In addition, recent advances in harvesting technology allowing spindle picking of cotton crops grown with 38 cm row spacings, may increase the benefits of these systems by avoiding the risk of trash discounts for fibre quality normally associated with stripper harvesters. Recent research in Australia with high-input cotton crops grown with 25 cm row spacings have not shown maturity or yield benefits. Studies were initiated to investigate whether differences in fruit retention offered by transgenic Bollgard II® cultivars affected the yield and maturity of cotton when grown at different row spacings. In 2004/05, we compared the yield and maturity of Bollgard II and non-Bollgard II cotton cultivars in four different row spacings (25 cm, 38 cm, 100 cm and 200 cm) with different plant populations. Neither lint yield nor maturity was significantly affected by UNR row spacing. Importantly, the Bollgard II cultivar had the same responses to row spacings as the non-Bollgard II cultivar. Despite the Bollgard II cultivar having earlier maturity than the non-Bollgard II cultivar there was no difference in yield. Yield components were affected: boll number increased as row spacing decreased, but boll size was smaller. The non-Bollgard II cultivar had higher boll number, but had smaller boll size. Fiber quality parameters were largely unaffected by cultivar or row spacing, although fiber length was longest in the 200 cm spaced crop suggesting less water stress at flowering, and the Bollgard II cultivar had longer but slightly weaker fiber than the conventional cultivar. The benefits of UNR systems compared with conventional spacing consequently remain uncertain and 38 cm rows responded similarly to 25 cm rows. Careful manipulation of crop growth through nutrition, irrigation and growth regulators may help realise benefits of UNR systems.

Introduction

Cotton (*Gossypium hirsutum*) production in Australia is expanding into areas with shorter growing seasons. This and increasing production costs have fuelled interest in production methods that reduce time to crop maturity. Cold temperatures slow crop establishment early in the season and reduce fiber quality late season. A shorter crop cycle means the crop can be planted later and harvested earlier, allowing these effects to be avoided. An alternative to conventionally spaced cotton (1 m or 39" rows) is ultra narrow row (UNR) cotton. UNR is a production system with rows spaced less than 40 cm (16") apart, which has shown potential for earlier maturity. UNR cotton production also has opportunities to save on harvesting costs using a stripper harvester, which is cheaper to buy and maintain, compared to spindle pickers. Conceptually, the high density planting of UNR reduces the time to crop maturity, as fewer bolls per plant need to be produced to achieve comparable yields to conventionally spaced cotton crops (Lewis 1971). Higher populations can also lead to earlier canopy closure and increased crop light interception leading to a more efficient use of light resources by the crop (Kreig 1996). In practice, this earliness has been difficult to achieve consistently in UNR trials in Australia and the U.S.

UNR cotton was initially conceived in the U.S.A. as a low-input production system to improve yield or profit margin to compensate for small plant size on marginal soils (Kerby *et al.* 1996). The main emphasis was on reduced harvesting and input costs without substantial yield loss (Kerby *et al.* 1996). In Australia, cotton is high yielding, usually irrigated and has high input management (fertilizer and insect control) (Hearn and Fitt 1992). High input, high plant population UNR cotton contrasts with earlier work into narrower row spacings that aimed to maximise yield without significant delays in maturity by using narrower row spacings to give more equidistant spacings between plants at the same plant populations as conventionally spaced cotton.

The development of new technologies in precision planting and harvesting equipment, as well as new transgenic cotton varieties with improved insect and weed control, has renewed interest in UNR. Information on the growth and development of UNR cotton compared with conventionally spaced cotton is limited, especially in high-input environments. A better understanding is needed to allow a more thorough analysis of the applicability of UNR in current and new production systems.

Genetically engineered (transgenic) cotton expressing genes from Bacillis thuringiensis (Bt) have recently been made available to cotton growers throughout the world (Perlak *et al.* 1990). In Australia, cotton growers now have access to Bt cotton that contain genes that express the insecticidal proteins Cry1Ac and Cry2Ab (Bollgard II®, Monsanto). Bollgard II cotton reduces the need to use chemical pesticides to control *Helicoverpa* spp., the primary early-season cotton pest in Australia, which can result in early fruit loss (Hearn and Fitt 1992). Improved early fruit retention of Bollgard II has meant that management practices are being revised in Australia and elsewhere (Dong *et al.* 2006; Hofs *et al.* 2006; Pettigrew and Adamczyk 2006). To gain earlier maturity in UNR production systems it is imperative that most of the bolls that are set are on lower branches, as these mature first (Constable and Gleeson 1977; Kerby *et al.* 1996). The use of high retention cultivars may assist in achieving earliness in UNR production systems. Increasing plant densities using UNR is considered as a viable management option for Bollgard II in Australia, as the Bollgard II licence there is based of area planted rather than amount of seed purchased.

This paper investigates whether the yield and maturity of Bollgard II cultivars differs from non-Bollgard II (non-Bt) cultivars in UNR spacings compared to conventionally spaced (39") rows.

Materials and Methods

A non-Bollgard II cultivar (Sicala V-2RR, CSIRO, Australia) and its closest Bollgard II equivalent (Sicala V-3BR, CSIRO, Australia) were compared in both 25 cm and 38 cm ultra-narrow (10" and 15"), 100 cm conventionally spaced (39") and 200 cm wide (78") rows in an experiment grown in Narrabri, NSW, Australia on a heavy clay soil. All row spacings were sown into a full moisture profile on beds at 2.0m spacing. The experiment was sown 26 October 2004. Established plant populations were 60 000 plants/ha for wide (200 cm) rows, 120 000 plants/ha for conventionally spaced (100 cm) rows, 240 000 plants/ha for 38 cm UNR and 180 000 plants/ha for 25 cm UNR. A randomised complete block design with four replicates was used. Nitrogen was applied as anhydrous ammonia at 146 kg N/ha two months before planting. Full irrigation and commercial insect control for the non-Bollgard II cultivar were used. There were five irrigations and nine insecticide applications.

At the end of the season, lint yield and crop maturity (60% bolls open) were determined from weekly hand picks. Fiber quality measurements were performed using a high-volume-instrument (HVI). Statistical analyses were conducted using Genstat® software. Unless stated otherwise significant differences were considered at 95% confidence intervals ($P < 0.05$).

Results and Discussion

Crop maturity, lint yield and yield components

There were no significant interactions between cultivar and row spacing for time to maturity (60% open bolls) in the experiment (Figure 1). The wide rows (200 cm) matured 4.8 days later than the other three row spacings (25 cm, 38 cm and 100 cm), but there was no difference in time to crop maturity between the conventionally spaced or either UNR treatment. As there was no limitation in resources the lower competition in the 200 cm row spacing, allowed those plants to grow larger and cutout later, hence delaying crop maturity. The Bollgard II cultivar matured 12.9 days earlier than the non-Bollgard II cultivar, suggesting higher early fruit retention across all row spacings.

There were no significant interactions between cultivar and row spacing for lint yield or gin out-turn in the experiment (Table 1). There were also no significant differences in lint yield or gin-out turn between the four row spacings. The results agree with our previous data comparing 25 cm UNR spaced cotton to conventionally spaced cotton which also found no differences in yield or maturity (Roche *et al.* 2003a; Roche *et al.* 2003b; Roche *et al.* 2004a; Roche *et al.* 2004b). Cotton's ability to adapt to a wide range of plant populations in 100 cm rows is well known from early studies, and more recent work assessing Bt cultivars have also found similar yield responses (Bednarz *et al.* 2006; Dong *et al.* 2006).

There were no significant interactions between cultivar and row spacing for number of bolls/m^2 or boll size in the experiment (Table 2). The number of bolls/m^2 was significantly lower in the conventionally spaced rows than in the wide rows or two UNR spaced treatments (Table 2). Lint weight per boll was not significantly different across row spacings. Total average boll size (seed cotton/boll) and seed weight per boll was significantly lower in the two UNR spaced treatments compared with the conventionally spaced treatment, but was not different to the wide rows. Several studies have found a decrease in boll size as row spacing decreases (Constable 1977; Galanopoulou-Sendouka *et al.* 1980; Bednarz *et al.* 2000). The smaller seed weight/boll may be do to smaller or fewer seeds per boll. Constable (1977) found that the smaller boll size in the narrow row (18 cm row spacing) treatments in his experiments was due to fewer seeds per boll compared to conventionally spaced rows; suggesting early competition or stress. Further investigations into this response are continuing.

The Bollgard II cultivar had significantly lower lint yield than the non-Bollgard II cultivar, but there were no different in gin out-turn (Table 1). Higher early boll loads would have led to earlier maturity and thus cutout in the Bollgard II cultivar, limiting the opportunity to take advantage of the full season for growth. The lint yields in this experiment for the non-Bollgard II cultivar were above average (Australian average yield 2001-2005 = 2078 kg lint/ha (3.7 bales/acre)) and suggests that 2004-05 season conditions and growing period had high yield potential. The duration of crop growth has been well correlated with yield in Australia for non-Bollgard II crops (Bange and Milroy 2004; Stiller *et al.* 2004). The number of bolls/m^2 was significantly higher in the non-Bollgard II cultivar compared to the Bollgard II cultivar (Table 2). Total average boll size (seed cotton/boll), lint per boll and seed weight per boll was significantly lower in the non-Bollgard II cultivar compared to the Bollgard II cultivar (Table 2).

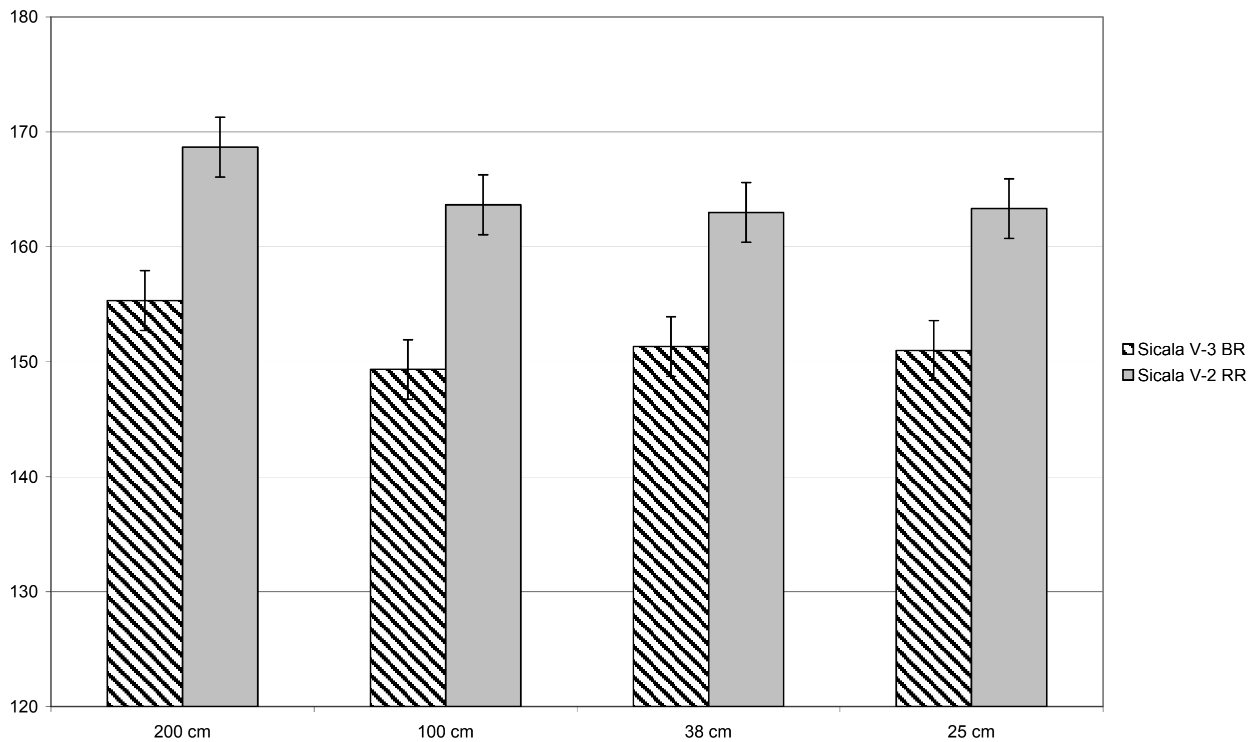

Figure 1. Days after sowing to maturity (60% open bolls) for 200 cm, 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05.

Table 1. Lint yield and Gin out-turn (% lint) for 200 cm, 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05. (Significant differences indicated by ** - 99% confidence level)

Row Spacing	Lint yield (kg/ha)		Gin out-turn (%)	
	Sicala V-3BR	Sicala V-2RR	Sicala V-3BR	Sicala V-2RR
200 cm	1928	2765	39.5	43.2
100 cm	2282	3192	40.5	43.8
38 cm	2566	2789	41.0	43.6
25 cm	2675	3128	39.5	44.2
LSD Row Spacing x Cultivar	*696*		*2.0*	
LSD Row Spacing	*492*		*1.4*	
LSD Cultivar	***348*		***1.0*	

Table 2. Boll number and boll size (lint/boll and seed cotton/boll) for 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05. (Significant differences indicated by ** - 99% confidence level * - 95% confidence level)

Row Spacing	Boll number/m^2		Lint/boll (g)		Seed cotton/boll (g)	
	Sicala V-3BR	Sicala V-2RR	Sicala V-3BR	Sicala V-2RR	Sicala V-3BR	Sicala V-2RR
200 cm	81.5	120.3	2.22	2.29	6.00	5.31
100 cm	103.0	144.2	2.37	2.23	5.47	5.10
38 cm	115.2	136.3	2.23	2.05	5.44	4.63
25 cm	136.8	144.2	1.94	2.18	4.90	4.99
LSD Row Spacing x Cultivar	*29.2*		*0.30*		*0.62*	
LSD Row Spacing	***20.6*		*0.22*		**0.44*	
LSD Cultivar	***14.6*		*0.15*		***0.31*	

Fiber quality

There were no interactions between row spacing and cultivar for fiber quality measurements (Table 3). The wide row spacing had significantly longer fiber than the three narrower row spacings but there were no other effects of row spacing on fiber length. This longer fibre length in the wide row spacing suggests that it had less water stress around flowering. The Bollgard II cultivar had significantly longer but shorter fiber compared to the non-Bollgard II cultivar. Apart for these subtle inherent differences between cultivars, there were no significant differences between cultivars for other fibre quality measurements. Discounts for high micronaire are of increasing concern to Australian producers. It has been suggested that the introduction of Bollgard II may have contributed to this issue, but in this study micronaire was not different between the Bollgard II and non-Bollgard II cultivars.

Table 3. Fiber quality measurements for 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05. (Significant differences indicated by ** - 99% confidence level)

Row Spacing	Length (dec. inches)		Strength (g/tex)		Micronaire	
	Sicala V-3BR	Sicala V-2RR	Sicala V-3BR	Sicala V-2RR	Sicala V-3BR	Sicala V-2RR
200 cm	1.19	1.15	33.2	33.1	4.4	4.5
100 cm	1.17	1.11	31.9	33.4	4.5	4.6
38 cm	1.16	1.11	32.5	33.9	4.5	4.5
25 cm	1.15	1.10	32.0	33.6	4.5	4.3
LSD Row Spacing x Cultivar		*0.03*		*1.1*		*0.4*
LSD Row Spacing		**0.02*		*0.8*		*0.3*
LSD Cultivar		***0.02*		***0.6*		*0.2*

Conclusion

There were no indications in this study that a Bollgard II cultivar performed differently to a non-Bollgard II cultivar when grown in different row spacings. More importantly, although the Bollgard II cultivar did mature earlier across all row spacings this did not result in earlier maturity in the UNR spacings. Careful manipulation of crop growth through nutrition, irrigation and growth regulators may help realise benefits of UNR systems. Further research into the key physiological processes of UNR production is continuing in order to understand and optimise the cotton grown under UNR in Australian production systems and assess it in a rigorous manner to establish its potential as an alternative system.

Acknowledgments

Thanks to Dr. Greg Constable for helpful discussion on the manuscript. Thanks also to Jane Caton, Graeme Rapp and Darin Hodgson for assistance in the field. This work was partially funded by the Cotton Research and Development Corporation.

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