



FINAL REPORT

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

Cotton CRC Project Number: 1.03.03

Project Title: Physiological Basis for Cotton Yields - Plant Configuration

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CRC Program: The Farm

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Final Report

Background

Narrow row cotton (rows spaced less than 40cm apart) has long been seen as a potential alternative system for Australian cotton, especially in regions with shorter growing seasons. The aim of these systems has been to reduce harvest costs and achieve earlier maturity without sacrificing yield. Further interest has been generated by recent advances in harvesting technology from John Deere that allow spindle picking of narrow row cotton crops (38cm rows), with claims of improved yield and earlier maturity while avoiding the risk of discounts for fibre quality associated with harvest.

Detailed studies to improve our understanding of differences in the growth and development of cotton in conventionally spaced (1m) and ultra-narrow row (UNR – 25cm row spacing) production systems were conducted as part of postgraduate studies by Rose Roche. She sought to understand the reasons for differences in growth between UNR cotton and conventionally spaced cotton when grown under similar agronomic management. Rose found that these systems do not differ in yield or timing of maturity, despite the clear differences in plant populations, size and light environments (interception and distribution). Rose's project also contributed to a more detailed understanding of cotton's responses to these practices and has suggested explanations based on sound crop physiological principles. This also provided an understanding of how other inputs or practices may be modified to achieve the goals of earlier maturity and similar yield.

Despite this research, there continued to be limited understanding of cotton's growth response to different row configurations (especially 38cm row spacing) in the warmer high-input Australian environments. Conceptually, in high-input systems, the high density planting of narrow row systems reduces the time to crop maturity, as fewer bolls per plant need to be produced to achieve yields comparable to conventionally spaced cotton crops. In practice, again this earliness has been difficult to achieve consistently in UNR trials in both Australia and the US despite the level of crop inputs.

The general theory of how cotton growth responds in narrow row is based on a few key assumptions:

- Closer spaced cotton closes the canopy faster than conventionally spaced cotton, leading to greater light interception earlier in the season.
- Smaller plants in UNR are less vegetative and will allocate a greater proportion of photoassimilates to boll production.
- A smaller plant with fewer bolls will mature earlier than a larger more vegetative plant.
- A plant grown in a high density environment has more plants which are each smaller and with less bolls than in a conventional system. These assumptions however, have not consistently held true. The assumption of greater yield potential through increased early

light interception can only be achieved if additional growth is partitioned into fruiting structures.

Advances in technology and positive commercial experience in shorter season production systems where Pix®, Bollgard II and Roundup Ready technologies are available has renewed interest in narrow row production across the industry. In certain regions with particular management strategies alternative row configurations may offer significant opportunities.

Aim and Objectives

This project aimed to enhance our understanding the interaction between crop yield and maturity with plant population (row configuration x within-row spacing) so that opportunities to achieve earlier maturity or higher yields can be exploited, and management strategies to allow this developed. This will fill a significant gap in our current knowledge of crop agronomy and management. The specific aims were:

1. Targeted research to improve understanding of the effects of plant population (via differences in row configuration (especially 38cm rows) and plant spacing) in different climates throughout the Australian cotton industry.
2. Explore how management factors (eg. mepiquat chloride (PIX®) and irrigation timing) can be used to manipulate the growth of cotton in narrow row cotton systems to achieve earlier maturity or higher yield.
3. To establish guidelines to assist growers to determine the suitability of narrow row production systems for their region and farms.
4. Utilise agronomy and physiology research tools to develop strategies to assist in the management of cotton with different plant populations to optimise yield and fibre quality.

Table 1: List of objectives and Milestones achieved during the course of the project.

Obj No.	Objective	Milestone	Performance Indicator	Yr 1	Yr 2	Yr 3	Completed
1	Document known literature on narrow row cotton systems (38cm)	Successfully documented known literature	Completed manuscript	✓			✓
2	Develop a physiological basis for the differences in cotton growth with different row configurations and plant populations	Undertake field experiments that compares narrow row configurations and different plant populations with conventionally spaced cotton	Completed field experiments, results analysed and documented	✓	✓		✓ Partly, as some experimental work to be published will occur after some

							publications from Rose's thesis
3	Compare different varietal traits in narrow row systems with different plant population	Undertake field experiments that compare Bollgard II and conventional varieties in narrow row systems and with different plant populations	Completed field experiments, results analysed and documented.	✓	✓		✓
4	Establish regional differences in the growth of cotton with narrow row systems and with different plant populations Reduced regional spread due to reduced funding	Undertake field experiments at three different regional locations that compare varieties in narrow row systems with different plant populations	Completed field experiments, results analysed and documented. Collaborate with or pass on results to local industry development officer	✓	✓	✓	✓
5	Develop understanding of the effects of different agronomic practices in narrow row systems with different plant populations	Undertake field experiments that vary irrigation and timing of growth regulators in narrow row systems with different plant populations	Completed field experiments, results analysed and documented.		✓	✓	✓
6	Establish strong links with researchers in the USA working on narrow row cotton systems	CONDITIONAL ON SEPARATE TRAVEL APPROVAL BEING OBTAINED Travel to the US and work with researchers on narrow row cotton issues.	Completed joint publications with US researchers.		✓		✓ Rose attended the Beltwide cotton conference in 2008
7	Communicate results of field studies of narrow row studies to scientific community and	Successfully communicated results of row configuration studies	Publish Journal Articles, Cottongrower articles and conduct industry and conference	✓	✓	✓	✓

	industry		presentations				
8	Develop industry guidelines on issues relating to different row configurations and plant population	Successfully develop a set of guidelines.	Preparation of a draft manuscript for industry review			✓	✗ Project officer left CSIRO before guidelines developed

Methods

In order to optimise management for any system it is important to understand differences in the way the crop responds to its environment. Identifying the physiological basis underlying the way the crop grows in narrow rows and with different plant populations will help us to better tailor cropping systems to the desired outcome, whether it be yield, fibre quality or maturity. Once we know clearly how the crop responds we can manipulate other aspects of agronomy (eg varieties, water, growth regulators and nutrition) to better take advantage of any benefits that these different systems may confer (Figure. 1). Measuring the growth of cotton under different plant population options (including narrow rows) in comparison with conventionally spaced cotton when grown with a consistent agronomic management strategy is the first step in gaining this understanding. From there the value of adding extra components to manipulate growth (eg growth regulators, fertiliser, water) can be explored. Ultimately though, to optimise the plant population and row configuration may mean developing a complete agronomic package that may differ from current agronomic practices in a number of ways.

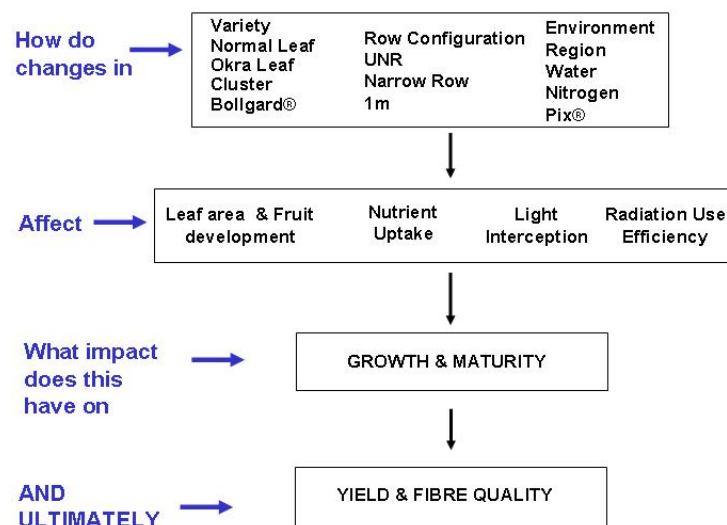


Figure 1: Process to develop understanding of cotton's responses to different production system.

This project supported detailed physiology/agronomic studies that quantify the effects (physiological basis) of different plant populations on cotton growth and ultimately on yield and fibre quality outcomes. Differences in plant population were mediated through changes in spacing between rows and within-row plant population (especially 38cm row spacing). It had a strong focus on field experiments in a range of different cotton regions. Measurements will include accurate recording of crop developmental stages, daily climate variables, crop growth rates, fruit development, crop maturity, yield and quality. This will allowed us to:

- i. Derive field-based response functions for a range of plant populations, row configurations and environmental and management processes affecting maturity yield and fibre quality. Derive field-based response functions of cotton growth for a range of plant population, row configuration environmental and management processes affecting maturity, yield and fibre quality. Particularly exploring the impact of early season plant development and its relationship to final yield and maturity. This would require in-depth measurements of water extraction by the roots, detailed nitrogen partitioning in plants, and comprehensive measurements of light interception, light environment and canopy development.
- ii. Derive a better understanding of the effects of specific manipulations of agronomy on the yield, maturity and fibre quality of different plant populations and row configurations (especially narrow row systems). Agronomic factors may include defoliation, crop nutrition (particularly nitrogen, phosphorus and potassium), effects of irrigation (timing, water deficiency and waterlogging) and the use of growth regulators (eg. PIX[®]).
- iii. To better quantify the differences in maturity, yield and fibre quality between Bollgard II (potentially high fruit retention crops) and conventional varieties with different plant populations and row configuration (especially narrow row systems).
- iv. Establish the relative benefits of using narrow row configurations for improving maturity, yield and quality for different regions. We would establish trials in cooler regions (Hillston, Breeza) and trials in warmer regions further north of Narrabri, (including Central Qld). Including warmer regions in the study helps us to better quantify the crop's response to population to different climates.

Results

During the course of the project a total of 13 field experiments were conducted. The type of experiments and their details are presented in Table 2. Many of the experiments were established in a manner that they were to meet the requirements of a number of objectives of this project. Broadly we will discuss the outcomes of the experiments, under three headings, they are:

- Growth of cotton in different row configurations (1,2,6,7,9,11,12,and 13)
- Growth of cotton grown in different row configurations and populations (2 and 9)
- Bollgard II vs. conventional (non-Bollgard II) in different plant populations (1,3,4,5 and 10)
- Agronomy of narrow row systems (6,7,8,11, and 13)

The numbers (see Table 2) in brackets denotes the experiment undertaken to meet the outcomes.

Table 2: List of field experiments conducted in this project.

Year	Experiment Type.	Location and Experiment No.	Treatments	Variety	Measurements
2004/ 2005	Fruit retention x Row spacing	Narrabri (1)	Bollgard II/Conventional 2m,1m, 38cm, 25cm row spacing	Sicala V3BR, V2RR	Early water use, nodes and heights, light interception, maturity, yield and quality
2005/ 2006	Row spacing x plant population	Narrabri (2)	1m, 38cm, 25cm row spacing 12, 24, 36 (only in 25cm rows) plant m ⁻²	Sicot 71BR	Early water use, nodes and heights, light interception, maturity, yield and quality
	Fruit retention x plant population	Narrabri (3) Moree (4) Hillston (5)	Bollgard II/Conventional 4, 8, 12, 16 plants m ⁻² (target plant populations)	Sicot 71BR, 71RR Sicot 71B, 71 Sicot 71BR, 71RR	Fruit retention, maturity, yield and quality
	38 cm Management	Narrabri (6) Hillston (7) Hay (8)	1m/38cm row x management (similar or responsive)	Sicot 71BR	Nodes and heights, light interception, maturity, yield and quality
2006/ 2007	Row spacing x plant population	Narrabri (9)	1m, 38cm, 25cm row spacing 12, 24, 36 (only in 25cm rows) plant m ⁻² (including treatment with lower plant number per row on inside rows on beds in 38cm spacing)	Sicot 71BR	Early water use, nodes and heights, light interception, maturity, yield and quality. Detailed growth analysis some treatments.
	Fruit retention x plant population	Narrabri (10)	Bollgard II/Conventional 4, 8, 12, 16 plants m ⁻² (target plant populations)	Sicot 71BR, 71RR	Fruit retention, maturity, yield and quality
	38 cm Management	Narrabri (11)	1m/38cm row x management (similar or responsive) including treatment that increased access to early water and nitrogen.	Sicot 71BR	Early water use, nodes and heights, light interception, maturity, yield and quality, plant samples for nitrogen uptake.
2007/ 2008	Row spacing	Narrabri (12)	2m,1m, 38cm, 25cm row spacing	Sicot 71BR	Early water use, nodes and heights, light interception, maturity, yield and quality. Detailed growth analysis some treatments.
	38 cm Management	Hillston (13)	1m/38cm row x management (similar or responsive)	Sicala 60 BRF	Nodes and heights, light interception, maturity, yield and quality.

Growth of cotton in different row configurations

A significant number of field experiments in this project were conducted to assess growth, maturity, yield and quality of cotton with various combinations of row spacing with changes in plant population. The row spacings that were compared with the traditional 1m row spacing were 2m, 38cm, and 25cm spacing. The comparisons discussed here assume all treatments were managed similarly (e.g. Pix was not applied to one treatment in exclusion to the others).

When comparing the narrow row spacings (25cm and 38cm) with 1m there were no statistical significant differences between the systems in their fibre quality. For crop maturity the narrow row did not generate early maturity consistently (Figure 2). Only on one occasion in the 07/08 season in Narrabri were the 25cm or 38cm spacings significantly earlier. When all data was analysed together neither was earlier than the 1m spacing. For yield the narrower spacings had statistically higher yields 3 out of 12 times over the project period. When this data was included with that collected from Rose Roche's thesis this comparison was 3 times out of 24 comparisons (Figure 3). However when all data from all experiments was combined and statistically analysed both the 25cm row spacing had significantly higher yields than the conventional row spacing of 1m. There was no improvement in yield of 38cm spacing compared to the 1m spacing. The improvement in yield in the 25cm spacing equated to 7% on average higher yield compared to the 1m spacing.

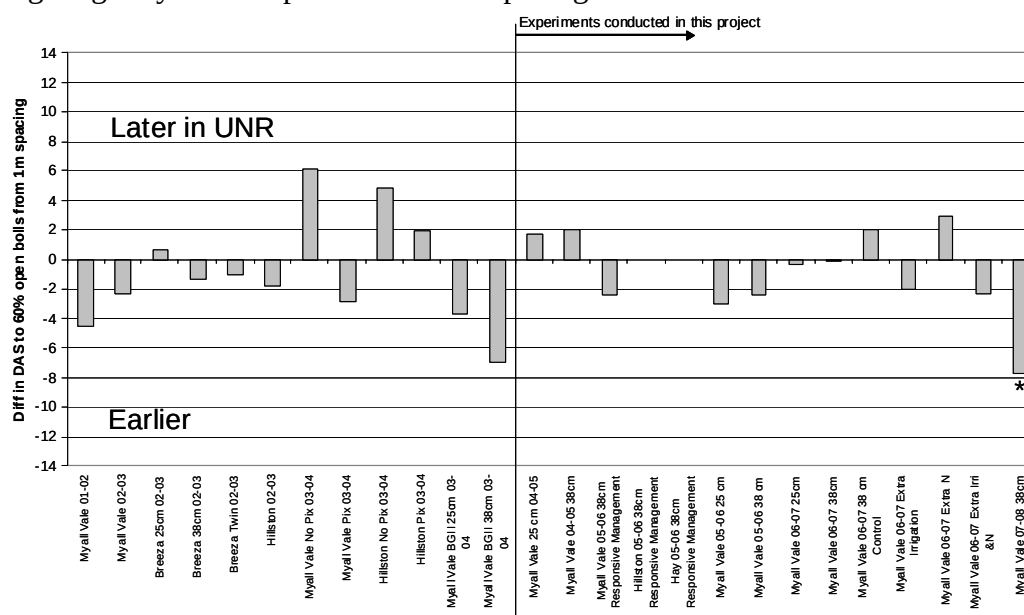


Figure 2: Difference in days to 60% maturity (60% bolls open) of narrow row spacings from the 1m row spacing treatment. Negative values mean that the narrow row spacings are earlier. Asterisks highlight those comparisons that were statistically significant ($P < 0.05$).

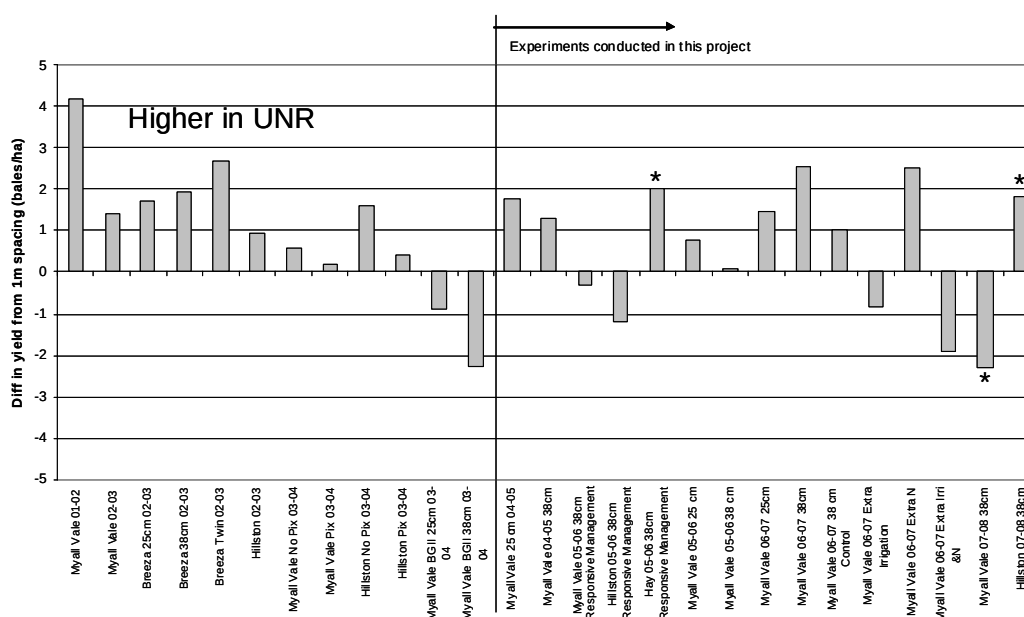


Figure 3: Difference in yield from the 1m row spacing treatment. Negative values mean that the narrow row spacings yield less. Asterisks highlight those comparisons that were statistically significant ($P < 0.05$).

These comparisons showed that while there was no benefit in using narrow production systems to attain earlier maturity, there was a tendency for the narrow row systems to produce higher yields, but there was considerable variation between seasons. Further discussion on the implication of these results will be discussed under the heading ‘Recommendations for Crop Management’ later in this report. Some of the outcomes of these comparisons have been published in Australian agronomy, Australian cotton and American Beltwide conference proceedings (papers 3,4,5 and 6 listed in this report). Results have also been presented at grower meetings in Hillston (on a least two occasions) and at Goondiwindi.

Growth of cotton grown in different row configurations and populations

Two field experiments in this project were conducted to assess growth, maturity, yield and quality of cotton with various combinations of row spacing with changes in plant population. The aim of this experiment was to determine if a more equidistant arrangement of plants using transgenic Bollgard II, Roundup Ready varieties gave a yield or maturity advantage. The row spacings that were compared with the traditional 1m row spacing were 38cm and 25cm spacing with populations equivalent to 12, 24, 36 (only in 25cm rows) plant m^{-2} . The comparisons again discussed here assume all treatments were managed similarly.

There were significant interactions between row spacing and plant density in Exp. 2 (Table 2). Lint yield was significantly higher in the 38 cm spaced rows at 12 plants m^{-2} compared with 24 plants m^{-2} but there was no significant difference in lint yield between 12 and 24 plants m^{-2} in the other row spacings. At 12 plant m^{-2} the 100 cm row spacing had significantly lower lint yield than the 25 cm and 38 cm row spacings; but there were no differences between row

spacings at 24 plants m⁻². In Exp. 9 there was no significant interaction between row spacings and plant densities. Numerically the response was also not the same as Exp. 1 with the highest mean lint yield in the 25 cm rows, 36 plants m⁻² and lower yields at 12 plants m⁻² compared with 24 plants m⁻² for each row spacing (Table 2). Overall the stability of cotton's yield and maturity response was maintained, with no consistent difference across inter- or intra-row spacings. No differences in fibre quality were again measured.

Table 3. Means for lint yield and crop maturity (days after sowing (DAS) 60% bolls open) for all treatments in Exps. 1 and 2. LSDs are presented for comparison between row spacings, differences in plant density, and the interaction between plant density and row spacing.

Experiment/Treatment	Lint yield (g m ⁻²)				Days after sowing to maturity (60% open bolls)			
	100 cm	38 cm	25 cm	Density Mean	100 cm	38 cm	25 cm	Density Mean
Exp. 2								
12 plants m ⁻²	274.5	325.5	308.0	303.2	150.5	146.4	148.2	148.4
24 plants m ⁻²	286.5	283.3	308.3	290.0	148.1	148.1	148.2	148.1
36 plants m ⁻²			279.7				148.0	
Row Spacing Mean	280.5	297.4	298.7		149.4	147.2	148.1	
LSD Row Spacing	19.8				2.8			
LSD Density				16.0				2.5
LSD Row Spacing x Density				**28.0				4.5
Exp. 9								
12 plants m ⁻²	224.8	235.4	236.9	232.4	152.9	154.1	152.8	153.2
24 plants m ⁻²	232.2	253.3	244.7	243.4	154.2	152.8	152.5	153.1
36 plants m ⁻²			258.4				152.8	
Row Spacing Mean	228.5	244.0	247.0		153.6	152.7	153.4	
LSD Row Spacing	24.9				2.1			
LSD Density				21.2				1.9
LSD Row Spacing x Density				36.7				3.2

**P < 0.01

In the second experiment we also added an additional plant configuration for the 38 cm row spacing with fewer plants on the two inside rows in an attempt to boost boll numbers these rows which usually yield less than the outside rows. The resulting treatment was a plant population of 18 plants m⁻² (12 plants/m outside rows; 6 plants/ m inside rows). Again this treatment did not change maturity or improve yield.

A publication for submission to Australian Journal of Agricultural Research is being prepared titled 'Performance of transgenic cotton (*Gossypium hirsutum* L.) in response to plant density. 2. Intra- and inter-row density. A draft copy of the paper is attached to the appendix of this report.

Bollgard II vs. Conventional in different plant populations

Recently, genetically modified (transgenic) cottons expressing genes from *Bacillus thuringiensis* (Bt) have been made available to cotton growers throughout the world. Bollgard II® offers significant potential to reduce pesticide use for the control of major Lepidopteran pests (particularly *Helicoverpa* spp. in Australia) and the potential for increased early fruit retention. Different morphology resulting from high fruit retention and intact mainstems may limit yield and further raise concerns with high micronaire. Both these issues maybe addressed by plant density. Five field experiments in this project were conducted to assess whether management guidelines for plant population differed between non-Bollgard varieties and Bollgard II varieties. The first experiment compared Bollgard II and non Bollgard II in 2m, 1m, 38cm, and 25cm row spacings in Narrabri in fully sprayed conditions. The other four experiments compared Bollgard II and non Bollgard on 1m row spacing with target plant populations of 4, 8, 12, 16 plants m⁻², again in fully sprayed conditions. Conducting the experiments in fully sprayed fields was undertaken to ensure bias pest control towards Bollgard II ensuring that these varieties had higher fruit retention.

In 2004/05, we compared the yield and maturity of Bollgard II and non-Bollgard II cotton varieties in four different row spacings (25 cm, 38 cm, 100 cm and 200 cm). Neither lint yield nor maturity was significantly affected by UNR row spacing. Importantly, the Bollgard II variety had the same responses to row spacings as the non-Bollgard II variety. Despite the Bollgard II variety having earlier maturity than the non-Bollgard II variety (Figure 4) there was no difference in yield (Table 4). Yield components were affected: boll number increased as row spacing decreased, but boll size was smaller. The non-Bollgard II variety had higher boll number, but had smaller boll size. Fibre quality parameters were largely unaffected by variety or row spacing, although fibre length was longest in the 200 cm spaced crop suggesting less water stress at flowering, and the Bollgard II variety had longer but slightly weaker fibre than the conventional variety.

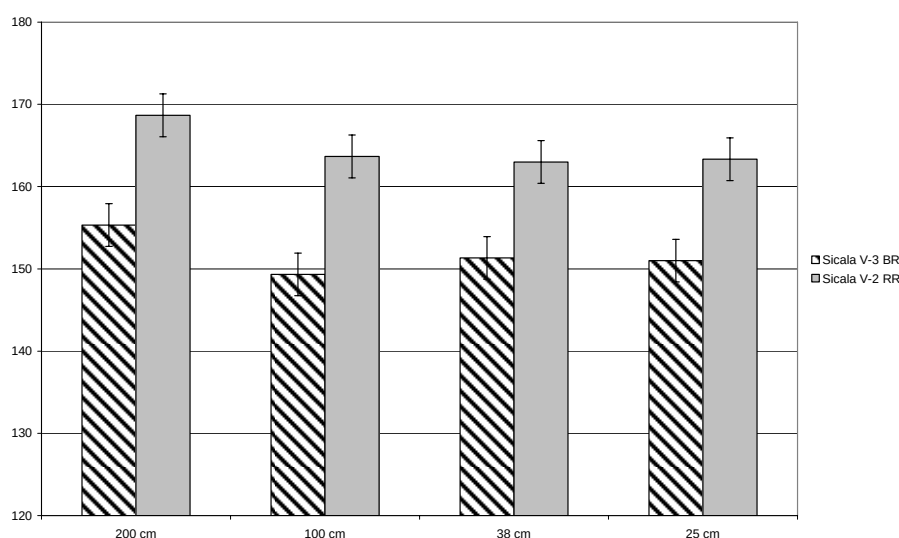


Figure 4: Days after sowing to maturity (60% open bolls) for 200 cm, 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05. The comparison between Bollgard II and non-Bollgard II is included. Error bars are the LSD.

Table 4. Lint yield and Gin out-turn (% lint) for 200 cm, 100 cm, 38 cm and 25 cm row spacing treatments in 2004-05. The comparison between Bollgard II and non-Bollgard II is included.

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
<i>LSD Row Spacing x</i>				
<i>Variety</i>	696		2.0	
<i>LSD Row Spacing</i>	492		1.4	
<i>LSD Variety</i>	**348		**1.0	

** $P < 0.01$

The other four experiments conducted on 1m row spacing over two season (05/06 and 06/07) were sown with target plant populations of 4, 8, 12, 16 plants m^{-2} . Again comparisons of yield and quality were made between Bollgard II than the non-Bollgard II varieties. Fruit retention was greater in Bollgard II than the non-Bollgard II variety, 7.8% higher across the experiments. The Bollgard II variety was also an average 11 d earlier but yield was not consistently affected. We also found no evidence to suggest that light interception was different between varieties or that Bollgard II plants were smaller or had less fruit per plant at harvest compared to non-Bollgard II varieties. Importantly, these differences did not translate into differences in the yield and fibre quality responses to plant density (2.8 to 16.4 plant m^{-2}) across seasons and regions. In addition, micronaire was not reduced by increasing plant density in either variety.

Across all these studies there was no evidence that earlier and higher fruit retention resulting from the use of Bollgard II varieties limited yield or led to interactions with plant density, and this study found that there is no reason to revise recommended plant densities for Bollgard II varieties in Australia. This study reemphasised the influence of changing plant

density in irrigated cotton is small, and found that this relationship is not different using genetically modified varieties.

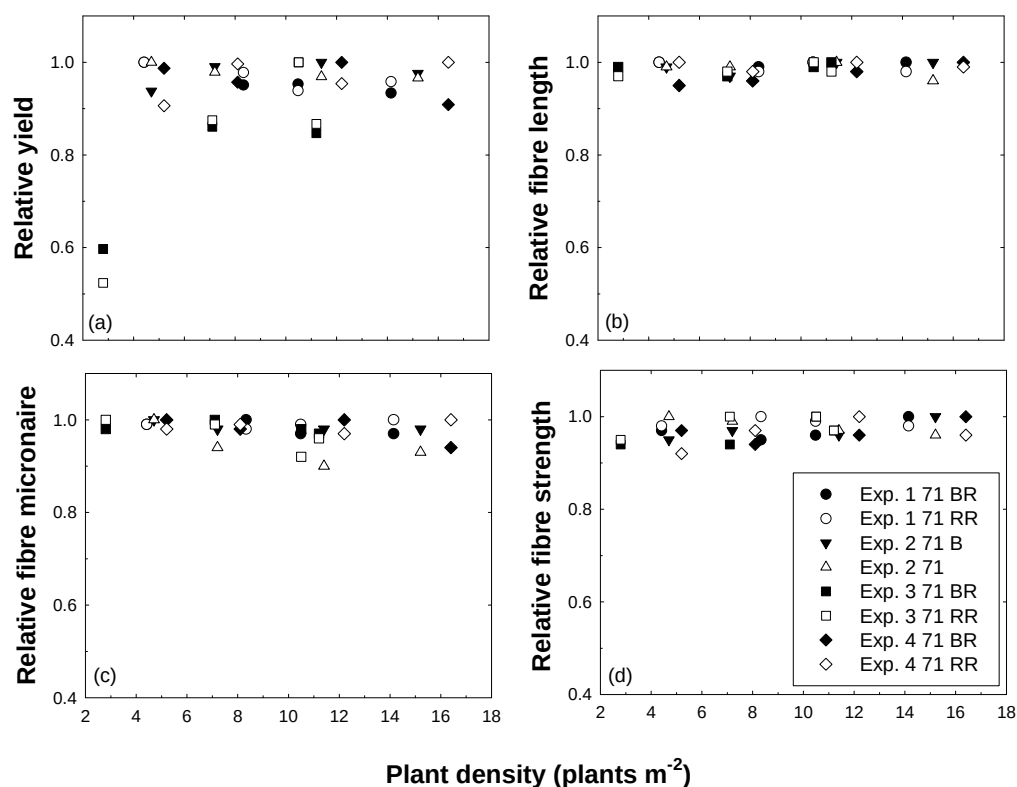


Figure 5: Relationships between relative (a) yield, (b) fibre length, (c) micronaire and (d) fibre strength and plant density for both Bollgard II (black symbols) and non-Bollgard II (white symbols) cultivars for all field experiments combined. Relative values calculated from average of treatment divided by the maximum average for the cultivar in that experiment.

Agronomy of narrow row systems

Previous research has shown that early plant competition in narrow systems limits the yield potential and negates any maturity benefits of narrower row spacings. This research focussed on comparing narrow row systems (25cm spacing) with 1m rows that were managed similarly. This part of the project sought to investigate whether other combinations of specific management practices could be used in narrow row systems (38cm spacings) that could contribute to higher yields and earlier crop maturity.

Following consultation with growers from the Hillston and surrounding regions (including involvement of the local industry development officer) it was agreed that a number of experiments be conducted to assess the impact of management on yield, fibre quality and maturity. A series of what was titled 'responsive management' experiments were conducted in Hillston, Hay and in Narrabri in the first year of the project. These were large scale field experiments with four treatments (1m spacing, 1m spacing responsive management, 38cm spacing, and 38cm responsive management). The responsive management treatments had plant heights and nodes monitored for vegetative growth rates, as well as plant nutritional status. If required these treatments would have Pix applied to address excessive vegetative growth or have additional nutrients applied as per individual needs. All other management practices were applied equally across all treatments.

In summary across all three experiments the narrow row spacing did not require different nutrient or growth regulator management compared to the 1m spacing. In terms of differences between the row spacing treatments yield was only significantly greater in the experiment conducted in Hay, and there were no differences in fibre quality or maturity across all experiments. At Hay there were however, concerns that the 1m spacing treatment had been unfairly biased as an inter-row cultivation treatment appeared to have caused damaged to plant roots. The results of these experiments were used in the overall analysis of the differences in 38cm and 1m row spacing comparisons presented previously in this report. Following on from these experiments a similar experiment was again conducted in Hillston in the last year of the project and again no differences in management needs were required.

As it was difficult to implement irrigation treatments in the responsive management experiments described above, a separate experiment investigating the impact of early season management for water and nitrogen was conducted in Narrabri in the second season of the project. The aim of this experiment was to assess whether higher inputs earlier in crop development in the narrow row (38cm) spacing would overcome any competition effects limiting yield and earlier maturity. The treatment comparisons included 1m and 38 cm row spacings with both higher N and water applied separately and together. An extra 60 kg/ha N and one extra irrigation were applied prior to first square. This experiment showed that an extra early irrigation did not benefit the 38 cm crop but rather led to increases in yield in the 1 m crop (Figure 6). There was also no response to extra Nitrogen application indicating that N levels were already adequate for crop growth. These results are important as they indicate that increasing early inputs does not alleviate the competition stress between plants and that the slowing of growth of the plants in UNR crops may be due to more complex physiological processes (eg. light competition) occurring in the crop.

Due to water limitations, we were unable to repeat this large-scale experiment in Narrabri.

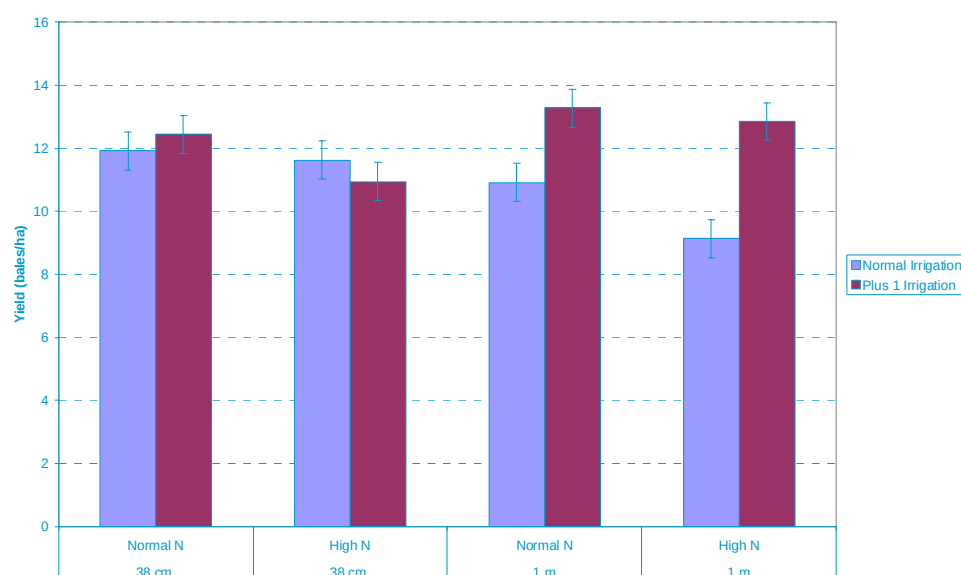


Figure 6: Yield results of experiment comparing the effects of early season management comparisons that aimed to increase water and nutrition to overcome early competition effects encountered in narrow row systems (38 cm). The error bars are the LSD.

Recommendations for Crop Management

In summary the outcomes of this project that were tangible and tested included the following:

- Plant population differences from both changes in inter and intra row spacing had little or no consistent response on yield, quality or maturity. Narrow row systems (38cm) did not improve yield or cause earlier maturity.
- The addition of earlier and higher inputs of water and nitrogen did not overcome plant competition effects leading to improvements in yield in 38cm row spacings.
- No differences in management were identified between 1m and 38cm row spacings. Pix management was not different, re-confirming results of Rose Roche's thesis.
- No differences were identified in the response of non-Bollgard II and Bollgard II varieties to changes in plant population (including row spacing).
- Uniform plant population is vital for achieving optimum yield.

Importantly the researcher working with growers on experiments undertaken in this project was able to identify a number of intangibles outcomes. These would need careful evaluation when narrow row systems are being considered as an alternative production system. The issues identified included:

- To enable narrow systems with adequate plant populations a quality precision planter is needed.
- Bed formation on different soil types at times effects establishment and efficiency of irrigation. Raised beds can be difficult to form in some soil types. There were also instances identified where beds were not adequately watered, despite long irrigation times.
- Picking is an issue. There is a need for specialised pickers for narrow row systems, which only are available from a limited number of contractors, with picking of crops often delayed. Picking efficiency was less in high yielding crops.
- Narrow row systems involve higher initial seed costs.
- Available weed control options in narrow row cotton are limited. Inter-row cultivation or spraying is not an option. Chippers also find it difficult to remove weeds effectively.

Management recommendations resulting from this work therefore include:

- There are no clear benefits of 38cm narrow row cotton systems for improving yield, quality and earlier maturity in Australian high input cotton systems on the majority of soil types on which cotton is grown.
- Management considerations for narrow row systems are not different to 1m row spacing.
- Intangible issues need to be evaluated when considering a change to narrow row production systems.
- No changes in management are needed for high fruit retention Bollgard II with changes in plant population.
- Uniform plant establishment is critical to maximise yield.

These messages have been communicated through a number of presentations at field days and conferences. In addition outcomes from both plant population studies conducted in Rose Roche's thesis and this project are being compiled into a research review that will be made widely available to the industry. As mentioned previously research from this project has also been compiled for submission to a referred journal for scientific review (see appendix).

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- Evan Brown, Scott Vaessen, Julie O'Halloran, and James Hill (IDOs)
- Staff at Tywnam Pastoral Co. "Merrowie"; Lachlan Farms "Brooklyn"; Ravensworth, Hay; and Glen Prairie, Moree (Grower cooperators)

Publications and Online Resources

Publications resulting from this project were:

1. Bange, M.P. and Roche, R. (2008). Do sowing rules change for high fruit retention transgenic cotton? Proceedings of the 14th Australian Agronomy Conference, 22-24 September 2008, Adelaide, South Australia.
2. Bange, M.P. Roche, R. and Caton, S.J. (2006). Impact of row configuration on high fruit retention (transgenic) rain-fed cotton systems. Proceedings of the 13th Australian Agronomy Conference, 10-14 September 2006, Perth, Western Australia.
3. Roche, R. and Bange, M.P. (2006). Do ultra-narrow row cotton systems offer any benefits to Australian farmers? Proceedings of the 13th Australian Agronomy Conference, 10-14 September 2006, Perth, Western Australia.
4. Roche, R., Bange, M.P. (2008). Impact of row configuration on high fruit retention (transgenic) varieties in high yielding, high-input cotton systems in Australia. In Proceedings Beltwide Cotton Conference January 8-11, Nashville, Tennessee.
5. Roche, R., Bange, M.P., Vaessen, S., Hely, T., and Mitchell, M. (2006). Which row spacing yields best? In Proc. 13th Aust. Cotton Conf. 7-10 August, Gold Coast Aust. The Aust. Cotton Growers Research Organisation.
6. Roche, R., Bange, M., Vaessen, S., Hely, T., Mitchell, M. (2006). Which cotton row spacing is better option for southern NSW? IREC Farmer's Newsletter. No. 173, pp. 17-19.
7. CSIRO Plant Industry Information Sheet <http://www.csiro.au/resources/UNRcotton.html>

Draft publications being prepared for submission to journal include:

Brodrick, R., Bange, M.P. (2008) Performance of transgenic cotton (*Gossypium hirsutum* L.) in response to plant density. 1. Intra-row. In preparation for submission to Australian Journal of Agricultural Research.

Brodrick, R., Bange, M.P. (2008) Performance of transgenic cotton (*Gossypium hirsutum* L.) in response to plant density. 2. Intra- and inter-row density. In preparation for submission to Australian Journal of Agricultural Research.

These publications are attached as an appendix to this report.

Presentations and field days

1. A seminar to a UNR/Pima Information Morning at Goondiwindi (24 August 2007, organised by Rod Gordon).
2. September (2007) a CottonTale on UNR and plant population research was produced with Susan Maas for Central Queensland and the Darling Downs.
3. Three Spotlight articles highlighting research results and the direction of current research.
4. Four industry field days (2 at Hillston, 1 at Warren, and 1 at Goondiwindi).

5. Twynam Agronomy Review in Forbes August 2008.
 6. Presentation to researchers at ACRI in 2007 and to West Tennessee Research and Education Center in Jackson (USA) in 2008.
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Final Report Executive Summary

Project Title: Physiological Basis for Cotton Yields - Plant Configuration

Principal Researchers: Dr R. Roche, Mr D. Hodgson and Dr M. Bange

Narrow row cotton (rows spaced less than 40cm apart) has long been seen as a potential alternative system for Australian cotton, especially in regions with shorter growing seasons. The aim of these systems has been to reduce harvest costs and achieve earlier maturity without sacrificing yield. Advances in technology and positive commercial experience in shorter season production systems where Pix®, Bollgard II and Roundup Ready technologies are available has renewed interest in narrow row production across the industry. In certain regions with particular management strategies alternative row configurations may offer significant opportunities. Further interest has been generated by recent advances in harvesting technology from John Deere that allow spindle picking of narrow row cotton crops (38cm rows), with claims of improved yield and earlier maturity while avoiding the risk of discounts for fibre quality associated with harvest.

Detailed studies to improve our understanding of differences in the growth and development of cotton in conventionally spaced (1m) and ultra-narrow row (UNR – 25cm row spacing) production systems were conducted as part of postgraduate studies by Rose Roche. Despite this research, there continued to be limited understanding of cotton's growth response to different row configurations (especially 38cm row spacing) in the warmer high-input Australian environments. Conceptually, in high-input systems, the high density planting of narrow row systems reduces the time to crop maturity, as fewer bolls per plant need to be produced to achieve yields comparable to conventionally spaced cotton crops. In practice, again this earliness has been difficult to achieve consistently in UNR trials in both Australia and the US despite the level of crop inputs.

This project aimed to enhance our understanding the interaction between crop yield and maturity with plant population (row configuration x within-row spacing) so that opportunities to achieve earlier maturity or higher yields can be exploited, and management strategies to allow this developed. This will fill a significant gap in our current knowledge of crop agronomy and management. During the course of the project a total of 13 field experiments were conducted that investigated: growth of cotton in different row configurations; growth of cotton grown in different row configurations and populations; Bollgard II vs. conventional (non-Bollgard II) in different plant populations; and agronomy of narrow row systems.

In summary the outcomes of this project that were tangible and tested included the following:

- Plant population differences from both changes in inter and intra row spacing had little or no consistent response on yield, quality or maturity. Narrow row systems (38cm) did not improve yield or cause earlier maturity.
- The addition of earlier and higher inputs of water and nitrogen did not overcome plant competition effects leading to improvements in yield in 38cm row spacings.
- No differences in management were identified between 1m and 38cm row spacings. Pix management was not different, re-confirming results of Rose Roche's thesis.
- No differences were identified in the response of non-Bollgard II and Bollgard II varieties to changes in plant population (including row spacing).
- Uniform plant population is vital for achieving optimum yield.

Importantly the researcher working with growers on experiments undertaken in this project was able to identify a number of intangibles outcomes. Therefore crop management recommendations resulting from this work therefore include:

- There are no clear benefits of 38cm narrow row cotton systems for improving yield, quality and earlier maturity in Australian high input cotton systems on the majority of soil types on which cotton is grown.
- Management considerations for narrow row systems are not different to 1m row spacing.
- Intangible issues need to be evaluated when considering a change to narrow row production systems.
- No changes in management are needed for high fruit retention Bollgard II with changes in plant population.
- Uniform plant establishment is critical to maximise yield.

These messages have been communicated through a number of presentations at field days and conferences. In addition outcomes from both plant population studies conducted in Rose Roche's thesis and this project are being compiled into a research review that will be made widely available to the industry.