

Why aren't ultra-narrow rows earlier than conventionally spaced rows in Hillston?

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Earlier maturity in cotton would counteract increasing production costs and facilitate the expansion of cotton production into areas with shorter growing seasons. Gaining earlier maturity without some yield penalty is difficult to achieve. Ultra-narrow row (UNR) cotton, a production system with rows spaced less than 40 cm apart, has shown potential for earlier maturity than conventionally spaced cotton (1 m apart), without substantial yield penalties. In practice, this earlier maturity has been difficult to achieve consistently in UNR trials in both Australia and the United States. Information on the growth and development of UNR cotton is needed to find out why. A trial in southwest NSW near Hillston compared cotton in ultra-narrow (25 cm row spacing) and conventionally spaced rows. Despite greater dry weight and fruit production in UNR earlier in the season, the competition for light and resources later in crop development negated these early benefits and did not translate into either earlier maturity or any increase in crop yield. The structure of the UNR cotton canopy meant that light was not penetrating through the top part of the plant to bolls lower in the canopy, perhaps delaying maturity. Studies are continuing into a greater range of environments and different population densities to further understand the key physiological processes of UNR production in order to optimise the system.

Introduction

Cotton production in Australia is expanding into areas with shorter growing seasons. Cold temperatures affect crop establishment early in the season and fibre quality at the end. A shorter crop cycle means the crop can be planted later and harvested earlier, allowing these affects to be avoided.

This and increasing production costs have fuelled interest in exploring production methods that reduce time to crop maturity. Gaining earlier maturity without some yield loss is difficult to achieve (Bange and Milroy, 2004). UNR is a production system with rows spaced less than 40 cm apart, which has shown potential for earlier maturity, without substantial yield loss.

There is limited understanding of cotton's growth response to different row configurations in the Australian environment. Most understanding of the growth, development and yield of UNR systems has come from research conducted in the United States. UNR systems in the US are low-input production systems aimed to improve yields on marginal soils to compensate for small plant size. In Australia UNR is grown commercially in high-input systems in areas with a shorter growing season.

In theory, if cotton is planted in ultra-narrow rows (less than 40 cm apart), the time to crop maturity would be reduced, as the increased plant density means fewer bolls need to be produced per plant to gain comparable yield to conventionally spaced cotton. In practice, this has been difficult to achieve consistently in UNR trials in Australia and the United States (Constable, 1977; Kerby et al., 1990).

The Ultra-narrow Row Theory

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

- Closer spaced cotton closes the canopy faster than conventionally spaced cotton, leading to greater light interception and better efficiency, with higher use of light earlier in the season.
- Smaller plants in UNR are less vegetative and will allocate a greater proportion of resources (photoassimilates) to boll production.
- A smaller plant with fewer bolls will mature earlier than a larger more vegetative plant.
- A higher plant density compensates for smaller plants with fewer bolls.

However, these assumptions 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. Greg Constable's work in the 1970s found that maturity and yield advantages were inconsistent; fruit shedding was significantly higher and bolls smaller in UNR (Constable, 1977). He also showed that higher leaf area early also did not favour rapid crop setting and that control of vegetative growth might be necessary to achieve earliness. Advances in technology and positive commercial experience in shorter season production systems where Pix®, Bt and RR technology are available has renewed interest in UNR.

Identifying the important changes in the way the crop grows in ultra-narrow rows and the influence on maturity and yield will help us better tailor cropping systems to the desired outcome, whether it be yield or maturity. Once we know clearly how the crop responds we can manipulate agronomy (eg varieties, water, growth regulators and nutrition) to better take advantage of any benefits that UNR may confer.

This paper summarises an experiment that compared UNR and conventionally spaced cotton at "Merrowie Station" (Twynam Pastoral Co.) near Hillston in the 2002-2003 cotton season.

Methods

Cotton grown in UNR and conventionally spaced rows were compared in an experiment grown at "Merrowie Station" (Twynam Pastoral Co.) near Hillston, NSW. Full irrigation and commercial pest control were used. The experiment was sown using Sicala V-3RRi on 2 m beds with 12 plants per linear metre. The ultra-narrow rows were 0.25 m apart and conventionally spaced rows 1 m apart. A randomised complete block design with four replicates was used (two treatments x four replicates = 8

plots). The experiment was sown on 4th October and watered-up on 7th October 2002. There were no Pix® (mepiquat chloride) applications on this experiment.

To determine dry weight production (leaf area, dry weight of fruit, leaf and stem) we harvested the plants in a 1 m² area of each plot three times over the season (first-square, peak flower and first open boll). On these dates we also measured light interception by the crop using a ceptometer. At the end of the season final height and node number, fruit retention per plant, crop maturity (60% bolls open) and yield were recorded. Fibre length and micronaire of ginned lint samples were measured using a high volume instrument (HVI).

Unless stated otherwise significant differences were considered at 95% confidence intervals ($P < 0.05$)

Results

There was no significant difference between UNR and conventionally spaced treatments in time to 60% maturity, lint yield, fibre quality (fibre length and micronaire), number of mature fruit (bolls) per metre, or boll size (Table 1). UNR cotton plants were significantly shorter and had fewer nodes than conventionally spaced plants (Table 1). Other experiments comparing UNR and conventionally spaced cotton have also found no earliness or yield advantage in UNR systems (Roche et al., 2003; Roche et al., 2004).

Table 1. Influence of row spacing on height, nodes, lint yield, 60% maturity, size and number of bolls, fibre length and micronaire (DAS = days after sowing; *Significant difference between row spacings)

Variable	Conventionally Spaced	UNR
Final Height (mm)	71*	53*
Final Nodes	21*	18*
Lint (g/m ²)	236	257
Boll size (seed cotton, g/boll)	3.38	3.24
Bolls/m ²	174	202
60% Maturity (DAS)	174	172
Fibre length (g/tex)	1.15	1.14
Micronaire	4.58	4.73

At 66 days after sowing (DAS) there were significant differences in dry weight production between UNR and conventionally spaced plots. The greater number of plants in the UNR cotton meant total dry matter and leaf area index were higher in the UNR crop (Table 2). Light interception was also greater in the UNR plots (Figure 1).

Table 2. Influence of row spacing on total dry matter, fruit dry matter, squares, green bolls and open bolls dry matter, leaf area index and ratio of fruit to vegetative matter at three harvests over the season (DAS = days after sowing; *Significant difference between row spacings)

Variable (per m ²)	Conventionally Spaced			UNR		
	66	108	150	66	108	150
DAS	66	108	150	66	108	150

Total dry matter (g)	62.9*	1182	2977	137.6*	1340	3135
Total fruit dry matter (g)	0.14	162.0	1115.4	0.09	238.0	1162.7
Squares dry matter (g)	0.14	30.1	N/A	0.09	22.4	N/A
Green bolls dry matter (g)	N/A	131.9*	1024	N/A	215.6*	1090
Open boll dry matter (g)	N/A	N/A	91	N/A	N/A	73
Leaf area index	0.18*	2.03	1.98	0.39*	2.06	2.25
Ratio of fruit to vegetative matter	N/A	0.14	0.38	N/A	0.18	0.37

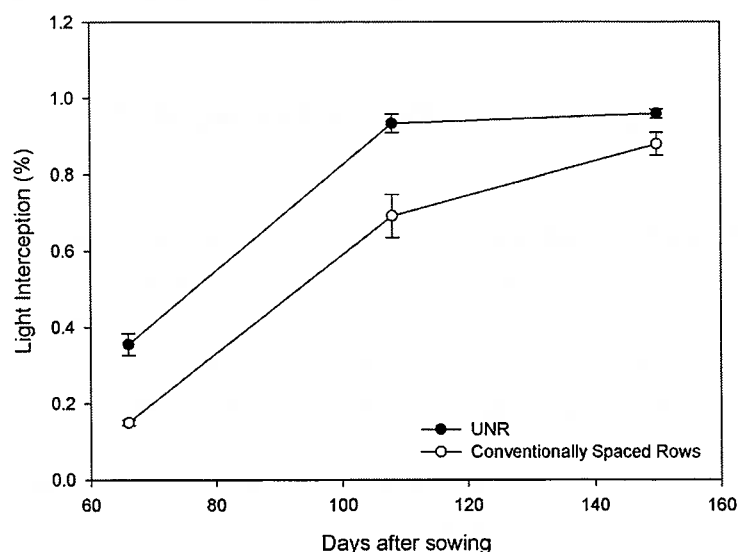


Figure 1. Percentage of light interception at midday by UNR and conventionally spaced canopies three times over the growing season in Hillston 2002-2003

At 108 DAS (peak flowering) there were no longer any differences in total dry matter or leaf area index between UNR and conventionally spaced plots (Table 2). There were however, differences in the number of bolls and boll weights with the UNR plots having a greater number and dry weight of bolls (Figure 2). Total fruit numbers (squares and bolls) were not different indicating that the UNR crop may have had either high fruit retention or was more advanced than the conventionally spaced crop. There were no differences in the ratios of dry weight allocated to fruit or vegetative matter. At this stage the UNR crop had already reached canopy closure (light interception > 80%) whereas the conventionally spaced crop was only at 69 % light interception (Figure 1).

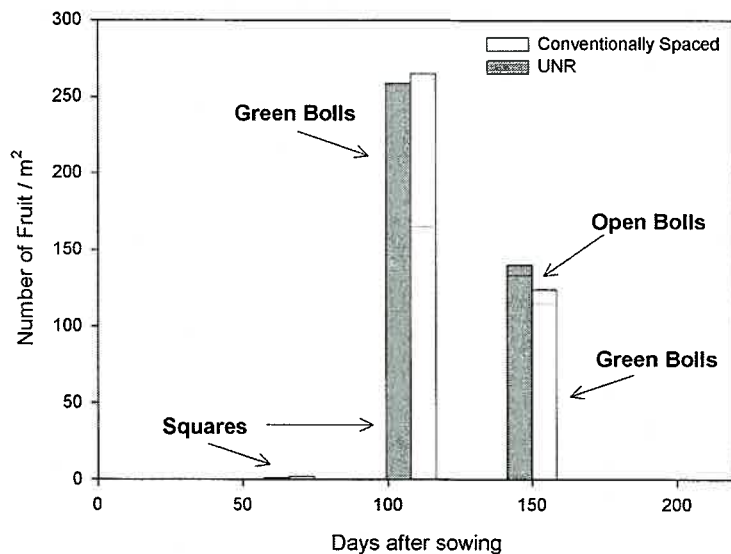


Figure 2. Total fruit numbers (number of squares, green bolls and open bolls) in UNR and conventionally spaced rows three times over the growing season in Hillston 2002-2003

At 150 DAS (first open boll) there were no differences in dry weight production, fruit numbers, and ratios of fruit to vegetative matter or light interception (Table 2 and Figure 1). As expected fruit dry weight in all plots had increased but fruit numbers had decreased and there were no longer any differences between conventionally spaced and ultra-narrow rows (Figure 2).

Fruiting dynamics of individual plants were significantly different with fewer total fruiting sites and fewer mature fruit in UNR plants (Table 3). There was no difference in fruit retention (Table 3) although other studies into UNR cotton have found that retention of fruit is significantly less in UNR crops than conventionally spaced cotton due to low light conditions (Kerby et al., 1990).

Table 3. Influence of row spacing on individual plant development in terms of number of fruiting sites, number of mature fruit (open bolls), and fruit retention (DAS = days after sowing; *Significant difference between row spacings)

Variable	Conventionally Spaced	UNR
Number of Fruiting Nodes	12.06*	8.62*
Number of Fruiting Sites per Plant	23.25*	12.06*
Number of Open Bolls per Plant	10.50*	5.69*
% Retention Overall per Plant	45.7	47.7
1 st Position Retention per Plant (%)	54.5	52.0
1 st Position Fruit (open bolls per plant)	6.50*	4.44*

In cotton crops fruit distribution is vertical through the canopy, so the amount of light available to leaves throughout the canopy is important to support boll growth. Total light interception measures the total amount of light intercepted by the crop but where this light is intercepted is also important. At 108 DAS although the total amount of light intercepted was higher, there was no difference in the

relative proportion of light intercepted at different layers vertically through the UNR canopy compared to the conventionally spaced canopy (Figure 3).

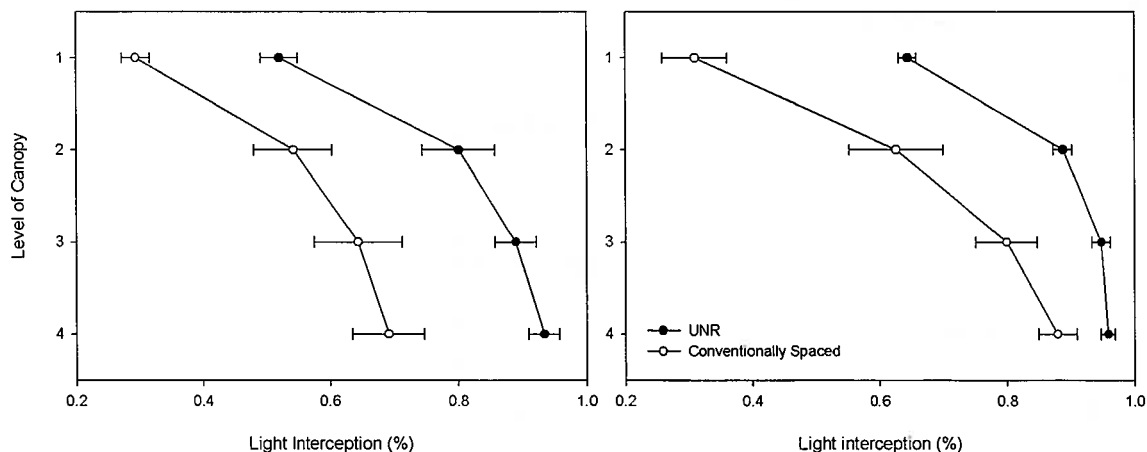


Figure 3. Light interception vertically through UNR and conventionally spaced rows at 108 days after sowing (left) and 150 days after sowing (right). (Level 1 being the top layer, level 4 the bottom).

At 150 DAS however, there were no differences in total light interception, but there was a difference in the relative proportion of light intercepted at different layers vertically through the UNR canopy compared to the conventionally spaced crop (Figure 3). The UNR canopy was structured so that 67% of the light was intercepted in the top layer and 25% in the second layer, with only 8% of light penetrating the bottom half of the canopy. In contrast in the conventionally spaced rows the canopy intercepted 70% in the top half and 30% in the bottom half.

This is because of differences in canopy structure. In a UNR crop because the plants are spaced so close together most of the light at the bottom of the canopy is that which penetrates through from the top of the canopy. Once the canopy closed those leaves in the top of the UNR canopy shaded those below and little light got through to the bottom leaves. In a conventionally spaced crop light not only comes from above but also from the sides, as the wider spaced rows means that the plants are not shaded by neighbours on all sides.

To see what impact this canopy structure had on yield we looked at yield distribution across the bed in the UNR plots (Figure 4). The outside row contributed 45% of the lint yield compared to the other two rows. This may be because more light was available to bolls lower in the canopy, causing higher retention, production of fruit or differences in maturity, but these were not separated into individual rows in this experiment.

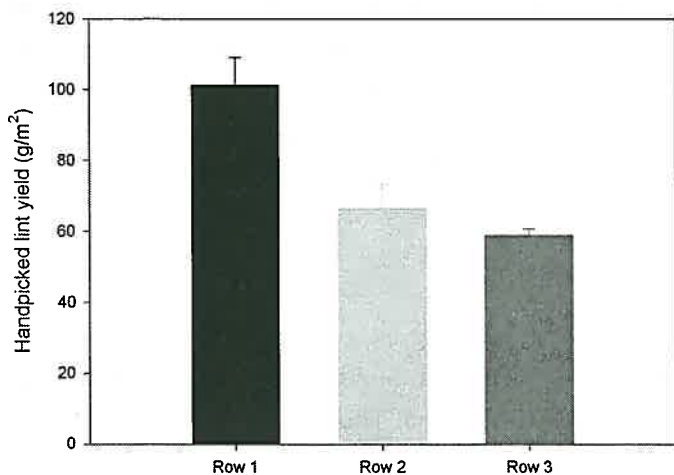


Figure 4. Lint yield of individual rows in UNR plots in Hillston 2002-2003. Row 1 is the outermost row next to the furrow, row 2 the next one in from the furrow and row 3 in the middle of the bed.

The high plant density (250 000 plants/ha) may have been another reason no significant differences in maturity and yield were observed in this experiment. The high plant density may have led to excessive competition for resources (photoassimilates) needed for fruit development. As high population densities are required to facilitate easy harvesting with a specialised UNR finger stripper harvester, further studies into UNR production systems with different row spacing, plant densities and environments are continuing. As the UNR plants did not partition more resources into fruit than vegetative matter manipulation with growth regulators or lowering the plant population per ha may help this and also increase light penetration to allow more resources for fruit development lower in the UNR canopy.

Conclusions

Looking at the key assumptions for earlier maturity in UNR some of these were met in this experiment:

- the UNR cotton closed the canopy faster than conventionally spaced cotton, leading to greater light interception with higher use of light earlier in the season, and
- the higher plant density compensated for smaller plants with fewer bolls and there was no yield penalty

however, two of the key assumptions were not met:

- smaller plants in UNR were not less vegetative and did not allocate a greater proportion of resources (photoassimilates) to boll production, and
- a smaller plant with fewer bolls did not mature earlier than a larger plant.

So, although the UNR crop intercepted more light earlier in the season and had fewer fruiting branches and fruit per plant these fruit did not mature earlier than those in the conventionally spaced crop, indicating that fruit set or development was delayed in the UNR canopy. The structure of the UNR

cotton canopy meant that light was not penetrating through the top part of the plant to bolls lower in the canopy perhaps delaying maturity. Retention was not an issue in this experiment although other studies into UNR cotton have found that retention of fruit is significantly less in UNR crops than conventionally spaced cotton due to low light conditions. Further studies are continuing into different row spacings, plant densities and the role of growth regulators to better understand canopy development and what affects earliness in a UNR crop.

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