Crop growth and maturity in ultra narrow row and conventionally spaced cotton

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Abstract

Earlier maturity in cotton has become important as production costs increase and production in Australia expands into areas with shorter growing seasons. Ultra narrow row (UNR) cotton, a production system with rows spaced less than 40 cm apart, has shown potential for earlier maturity without substantial yield loss. In practice, this earlier maturity has been difficult to consistently achieve in UNR trials in both Australia and the United States. Information on the growth and development of UNR cotton is required to allow a more thorough analysis of the potential applicability of UNR in Australia compared with conventional 1 m row spacing. A growth analysis trial in northwest NSW compared UNR (25 cm row spacing) and conventionally spaced cotton. Despite greater early season leaf area development and light interception in UNR, the competition for light and resources later in crop development negated these early benefits and did not translate into earlier maturity or improved crop yield. UNR cotton had a higher overall light extinction coefficient and lower radiation use efficiency. 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.

Key Words

Light interception, biomass partitioning, *Gossypium hirsutum*.

Introduction

Cotton production in Australia is expanding into areas with shorter growing seasons. This and increasing production costs have fuelled interest in exploring production methods that reduce time to crop maturity. 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. An alternative to conventionally spaced cotton (1 m rows) is ultra narrow row (UNR) cotton. UNR is a production system with rows spaced less than 40 cm apart, which has shown potential for earlier maturity. 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 (1). In practice, this earliness has been difficult to achieve consistently in UNR trials in Australia and the U.S. (2,3).

The development of new technologies in precision planting and harvesting equipment, as well as new cotton varieties has renewed interest in UNR. In the U.S. there has been a resurgence of research into UNR but much of the research has focused on the agronomic level and there is little information on the physiology of UNR production systems in Australia. Information on the growth and development of UNR cotton is required to allow a more thorough analysis of the applicability of UNR in current and new production systems compared with conventionally spaced cotton. Light is thought to be a key factor in UNR systems with higher density plantings more efficiently utilising light resources earlier in the season, translating into faster crop growth and earlier maturity (4). This paper reports on initial investigations into UNR cotton that used a simple growth analysis to examine the differences between UNR and conventional cropping systems, in terms of leaf area development, light interception characteristics and biomass production and partitioning.

Methods

UNR and conventionally spaced production systems were compared in an experiment grown in Narrabri, NSW. UNR plots consisted of six rows spaced 0.25 m apart on a 2 m bed sown with 36 plants/m^2 and conventionally spaced plots of two rows spaced 1 m apart on a 2 m bed sown with 12 plants/m^2. A randomised complete block design with four replicates was used. Nitrogen was applied as anhydrous ammonia at 120 kg N/ha four months before planting. Sicala V-3RRi was sown 16th November 2001. Full irrigation and commercial insect control were used.

Starting just before first square, 0.5 m^2 plant samples were harvested approximately every 10 days and leaf area, dry weight of fruit, leaf and stem determined. Biomass components were converted into glucose equivalents for comparison (5). Intercepted solar radiation by the canopies was measured using tube solarimeters. Plant height and number of mainstem nodes were recorded weekly. At the end of the season fruit retention per plant, crop maturity (60% bolls open) and yield were determined. Fibre quality measurements on ginned lint samples were performed using a HVI (high volume instrument) to obtain fibre length and micronaire (a measure of fibre fineness and fibre maturity).

A simple growth analysis approach (6) was used to compare growth determinants between UNR and conventionally spaced treatments. Statistical analyses were conducted using Genstat? software. 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, yield of lint, fibre quality (fibre length and micronaire) and number of mature fruit (bolls) per metre, but boll size was significantly smaller in UNR cotton (Table 1). UNR cotton plants were significantly shorter and had fewer nodes than conventionally spaced plants (Table 1).

Table 1. Influence of row spacing on height, nodes, lint yield, 60% maturity, size and number of bolls, fibre length, micronaire, LAI, total dry matter (TDM), k, RUE, and cumulative intercepted solar radiation (n.s.d = no significant difference; SE = Standard error of the mean).

Variable	Conventional	UNR	Pooled SE	Significance
Final Height (mm)	880	605	20	($P < 0.001$)
Final Nodes	18.73	14.82	0.38	($P < 0.001$)
Lint (g/m^2)	243	338	50	n.s.d
Boll size (seed cotton, g/boll)	5.70	3.60	0.07	($P < 0.001$)
Bolls/m^2	101	146	22	n.s.d
60% Maturity (DAS)	149	144	2	n.s.d

Fibre length (mm)	28.96	28.70	0.20	n.s.d
Micronaire	3.93	3.93	0.07	n.s.d
LAI (96 DAS)	2.86	4.07	0.03	(*P* < 0.001)
Final TDM (g)	2771	2110	293	n.s.d
k	0.38	1.26	0.08	(*P* < 0.001)
RUE (g/MJ)	1.63	1.04	0.06	(*P* < 0.01)
Cumulative Intercepted Solar radiation (MJ/m^2)	1376	2018	357	n.s.d

Significant differences were also found between UNR and conventionally spaced crops in terms of radiation use efficiency (RUE), canopy light extinction co-efficient (k), and leaf area index (LAI) (Table 1 and Figure 2). The UNR crop reached maximum light interception earlier than the conventionally spaced crop (Figure 1) but there was not a significant difference in cumulative intercepted solar radiation at the end of the season (Table 1). The partitioning of resources to reproductive growth (allometric partitioning) was significantly higher in the UNR crop compared to the conventionally spaced crop (Figure 4). Total dry matter did not differ between UNR and conventionally spaced cotton (Table 1 and Figure 3). Fruiting dynamics of individual plants were significantly different with fewer total fruiting sites and fewer mature fruit in UNR plants (Table 2). There was no difference in fruit retention (Table 2).

Table 2. Influence of row spacing on individual plant development in terms of number of fruiting sites, number of mature fruit (open bolls), and fruit retention (n.s.d = no significant difference; SE = Standard error of the mean).

Variable	Conventional	UNR	Pooled SE	Significance
Number of fruiting sites per plant	24.20	14.60	1.90	(*P* < 0.01)
Number of open bolls per plant	6.22	3.64	0.75	(*P* < 0.05)
% Retention overall per plant	25.40	24.70	2.20	n.s.d

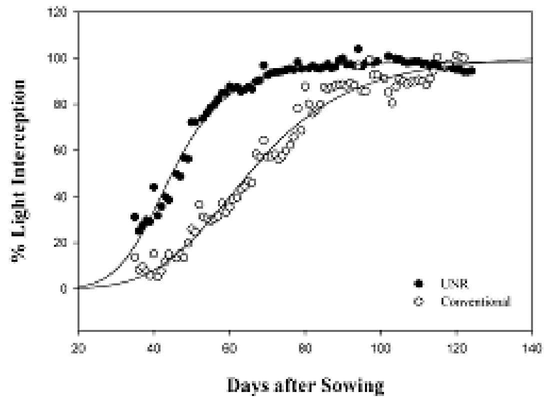

Figure 1. Comparison of average light interception between UNR and conventionally spaced cotton

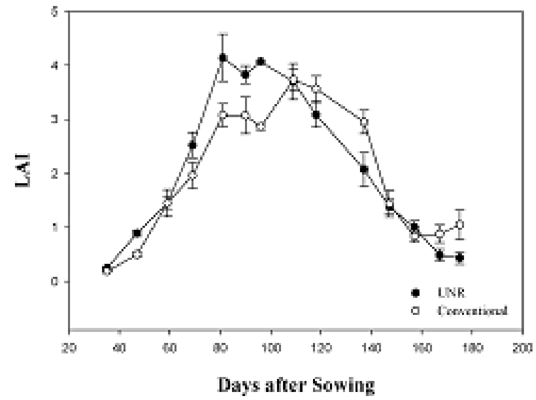

Figure 2. Average LAI of UNR and conventionally spaced cotton during the growing season

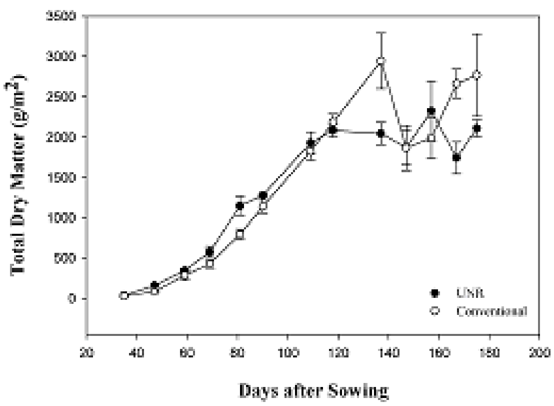

Figure 3. Total dry matter over the growing season in UNR and conventionally spaced crops

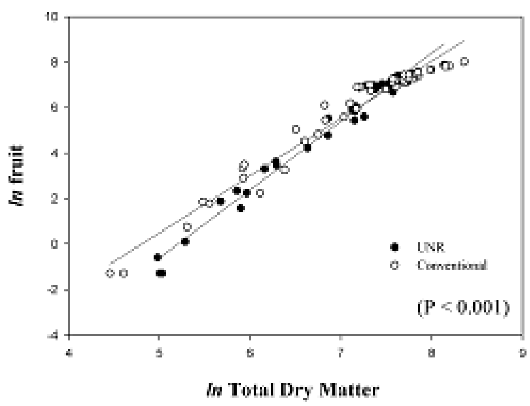

Figure 4. Comparison of allometric partitioning between UNR and conventionally spaced crops

Discussion

There were no significant benefits in yield or maturity using a UNR system. Although the UNR cotton initially had greater light interception, this did not translate into differences in final cumulative light interception, final total dry matter or yield due to the lower RUE of the UNR crop. RUE may have been lower in the UNR crop as LAI continued to increase after the crop had reached maximum light interception, continuing to commit photo-assimilates to producing new leaves that were not increasing light interception (7). The UNR crop produced a canopy structure that did not allow light to penetrate through the canopy indicated by a higher canopy light extinction coefficient (k) in the UNR crop. The consequences of this higher k in the UNR cotton meant less light was available to leaves lower in the canopy that are important for supporting boll growth. This was supported by light measurements taken through the canopy (data not shown).

The rate of dry matter partitioned into fruit was higher in UNR crops, as fewer resources were put into the stem and leaves in the more compact UNR plants. Research in the U.S. has also found that as row spacing decreased reproductive partitioning efficiency increased (8). The shorter and more compact UNR plants produced fewer fruiting sites and mature fruit per plant. These responses to higher plant populations and narrow row spacings have been found in a number of studies (2,9,10). Although fewer fruit were produced per plant, the higher plant density resulted in there being no significant difference in fruit number per unit area. While there was no significant difference in number, there were numerically more fruit in the UNR which compensated for the smaller size; thus the lack of significant differences in yield. The smaller boll size in the UNR crop suggests that there may have been limited photo-assimilates for fruit development, however this did not have a detrimental impact on fibre quality which has been observed in other studies (11). Several studies have found a decrease in boll size as row spacing decreases although the reasons for smaller fruit have not explicitly been explored (2,9-11). Retention was not an issue in this study 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 (3,10).

The responses of the UNR crop production system in this study, with no difference in maturity and reduced RUE could be due to the high population density in the UNR system which may have led to excessive competition for resources. The change in canopy structure in the UNR crop reducing the light to the lower parts of the canopy may have affected the balance between higher LAI improving the crops ability to intercept light and produce carbohydrates, and high LAI leading to intense shading and limiting plant carbohydrate production per plant (2,4,10). 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 population densities and environments are continuing.

Conclusion

The light environment in UNR cotton has significant implications on the ability of the plant to efficiently convert light into carbohydrates. Leaf area development was more rapid in the UNR crop, leading to higher early light interception but RUE was lower. Canopy structure was different in the UNR crop reducing the amount of light penetrating through the canopy. The increased partitioning of dry matter into fruit in the UNR crop suggests UNR cotton does have the potential to produce comparable yields to conventionally spaced cotton in a shorter period of time but this earliness was not achieved in this study. Further research into the key physiological processes of UNR production is continuing in order to understand and optimise the system.

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