2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

DOES A DIFFERENT PLANT TYPE ENHANCE PERFORMANCE OF UNR COTTON PRODUCTION SYSTEMS?

Rose Roche
CSIRO Plant Industry Cotton Research Unit
University of Queensland
Narrabri, AUSTRALIA
Michael P. Bange
CSIRO Plant Industry Cotton Research Unit
Narrabri, AUSTRALIA
Stephen P. Milroy
CSIRO Plant Industry Centre for Environment and Life Sciences
Wembley, AUSTRALIA
Graeme L. Hammer
University of Queensland
Queensland Department of Primary Industry
St. Lucia, AUSTRALIA

Abstract

Ultra narrow row (UNR) cotton production has the potential for earliness and cheaper harvesting in shorter growing seasons. This earlier maturity has been difficult to achieve in UNR trials in Australia and the U.S. Growing varieties with different morphological traits (compact, short fruiting branches and few vegetative branches) may optimise this alternative production system. A cluster line (short fruiting internodes) was compared to a normal branching variety in both UNR and conventionally spaced cotton crops in northwest NSW, Australia. There were few interactions between variety and row spacing. The cluster line did not confer any yield or maturity benefits over the normal variety in the UNR production system. The UNR crop did not exhibit earlier maturity or increased yield compared to the conventionally spaced cotton crop. The UNR cotton initially had greater light interception and intercepted more light over the growing season, but this did not translate into differences final total dry matter, yield or earlier maturity. Retention was affected by row configuration with lower retention in the UNR crops compared to conventionally spaced cotton, which may have impacted on any maturity or yield benefits. Further research into the key physiological processes of UNR production is continuing in order to better understand and optimise the system.

Introduction

Cotton (*Gossypium hirsutum*) 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 fiber quality at the end. 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 through the use of 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 (Krieg, 1996). In practice, this earliness has been difficult to achieve consistently in UNR trials in Australia and the U.S.

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

Previous research into UNR cotton production systems in Australia and the US has highlighted the need for cotton varieties better suited for UNR production systems (Kerby et al., 1996). Many authors suggest that varieties with different morphological traits (such as determinate varieties that are compact with short fruiting branches and few or no vegetative branches) are needed to optimise the performance of UNR cotton but this theoretical ideal has been little tested (Fowler and Ray, 1977; Heitholt and Stewart, 1999). This paper compares yield and maturity of a breeding line with cluster growth habit (short fruiting internodes) with a conventional variety in both UNR and conventionally spaced systems.

Materials and Methods

A cluster breeding line and its conventional sister line (Sicala 40) were grown in both UNR and conventionally spaced production systems in an experiment grown in Narrabri, NSW, Australia on a heavy clay soil. The cluster line contained both short fruiting branches and a high frequency of adventitious fruiting branches. UNR plots consisted of six rows spaced 0.25 m (10") and conventionally spaced plots of two rows spaced 1 m (39") apart on 1.8 m beds. Established plant populations were 105 000 plants/acre and 40 500 plants/acre respectively. A randomised complete block design with three replicates was used. Nitrogen was applied as anhydrous ammonia at 120 kg N/ha (107 lb N/acre) two months before planting. The trial was sown 11th October 2002. Full irrigation and commercial insect control were used.

The crop was monitored over the season and time to first square, first flower and number of nodes above the first position white flower (NAWF) recorded. Twice during the season (at first flower and first open boll) 1 m^2 plant samples were harvested and leaf area, dry weight of fruit, leaf and stem determined. Biomass components were converted into glucose equivalents for comparison (Wall et al., 1994). The light intercepted by the canopies was measured weekly using a Delta-T sunfleck ceptometer. At the end of the season plants were harvested at maturity for plant mapping and fruit retention per plant, time to crop maturity (60% open bolls) and yield were determined. Fiber quality measurements on ginned lint samples were performed using a HVI (high volume instrument) to obtain fiber length and micronaire.

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 Development and Maturity

There were no significant interactions between variety and row spacing in node of first fruiting branch, days after sowing (DAS) to first flower, first square, number of nodes above white flower (NAWF) or maturity (DAS to 60% open bolls).

The cluster line had a lower node to first fruiting branch at around node seven than the normal variety at around node nine (Table 1). The cluster line reached 50% first square an average of 11 days earlier and flowered 7 days earlier than the normal variety (Table 1). Maturity was only significantly affected by variety with the cluster line reaching maturity an average of 5 days earlier across both row spacings than the normal variety (Table 1). Time to five nodes above first position white flower (NAWF recommended to estimate cut-out (Bourland et al., 2001)) did not differ between varieties.

Both varieties squared 3-6 days earlier and flowered 5 days earlier in the conventional row spacing than the UNR crop (Table 1). Time to five NAWF was significantly shorter in the UNR row spacing compared to the conventional, however at 4 days earlier this is not practically significant (Table 1). This difference in cut-out was not reflected in differences in time to maturity.

The cluster did not confer any advantage in terms of maturity in the UNR cotton crop. The greatest effect on maturity in terms of crop development from this trial appears to be the node to first fruiting branch. Although both variety and row spacing had significant differences at early flowering stages, by cut-out these differences were minimal and at maturity row spacing no longer gave the crop a maturity advantage with the cluster line being earlier maturing regardless of row spacing.

Plant Height and Main Stem Nodes

There was a significant interaction between variety and row spacing for the final number of nodes but no interaction for height. The different varieties and row spacings significantly affected final plant height and number of mainstem nodes.

The cluster line was significantly taller but had fewer nodes compared to the normal variety across both row spacings (Table 1).

Both varieties were shorter with fewer nodes in the UNR row configuration compared to the conventional spacing. These responses to higher plant populations and narrow row spacings have been found in a number of studies (Bednarz et al., 2000; Constable, 1977; Galanopoulou-Sendouka et al., 1980).

There was an interaction between number of nodes in the varieties and row spacing. Indicating that the growth of the cluster line may have been different to that of the normal variety in the UNR row spacing. This is however difficult to determine as only final node and height measurements were taken in this trial.

Fruiting Positions and Retention

There were significant interactions between row spacings and varieties for total fruiting sites per plant, number of open bolls per plant and number of second position fruit indicating that the reduced plant size of the UNR crop may have impacted the two varieties differently.

Individual plant mapping at maturity showed that a normal variety plant had more fruiting sites compared with the cluster line but there were no differences in total number of open bolls per plant as first position fruit retention was similar and overall fruit retention better in the cluster line (Table 2).

First position and overall fruit retention was significantly higher in the conventional crop compared to the UNR crop. This is consistent with other studies that have found low fruit retention often characteristic of UNR crops (Galanopoulou-Sendouka et al., 1980; Kerby et al., 1990). Looking at the distribution of the fruit on the plants we found that there were no differences in number of fruit on the first four fruiting branches between row spacings, but there was significantly less fruit in fruiting branches higher in the plant (Figure 1). This indicates that retention was lowest at the fruiting nodes that developed later in the UNR crop, so although the crop kept putting on fruiting sites these were not contributing to any increase in yield and were perhaps delaying maturity of those bolls present.

The number of second position fruit was also significantly lower in the UNR crop compared with the conventionally spaced crop. However, this reduction was only apparent in the normal variety with a 75% reduction in the number of second position compared to a 4% reduction in second position fruit for the cluster line in a UNR spacing. This may be due to a higher number of adventitious fruit in the cluster line in the UNR spacing as UNR spacing usually results in a reduction of second position fruit (Jost and Cothren, 2000). The number of adventitious fruit was not specifically recorded in this study, but the lack of an impact on the number of second position fruit could potentially be an important advantage of cluster lines in UNR systems in terms of yield and may need to be further explored.

Light Interception and Biomass

There were no significant interactions between row spacing and variety for light interception, estimated radiation use efficiency (RUE), total dry matter or reproductive dry weight to plant dry weight ratios (harvest index).

Canopy closure, total cumulative light interception, approximate radiation use efficiency (RUE - dry matter produced per cumulative MJ of light intercepted at time of biomass harvest) and total dry matter at 69 DAS and 131 DAS did not differ between the two varieties (Table 3). The cluster line had a harvest index compared to the normal variety (Table 4). This may have contributed to earliness of the cluster line as the cluster line started fruiting earlier and with less resources going into vegetative growth it would have had more available for boll growth.

The UNR canopy intercepted more light than the conventional crop early in the growing season intercepting 80% of the light 21 to 27 days earlier than the conventional crop (Figure 2). Total accumulated solar radiation intercepted by the crop over the season was also significantly higher in the UNR crop compared to the conventional crop (Table 3). Early canopy closure and greater light interception is one of the reasons that UNR cotton production is considered to have the potential for earlier maturity. How efficiently the crop converts this light into biomass production is also important and the UNR crop had higher approximate RUE at the first harvest date (69 DAS) than the conventional crop but by the second harvest date RUE was not affected by row spacing (Table 3). The lower retention in the UNR crop may have been due to early canopy closure in the UNR crop and the competition between plants for light may have meant less light was available for fruit lower in the canopy causing shedding of fruit. 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 (Galanopoulou-Sendouka et al., 1980; Kerby et al., 1990). Total dry matter production was also higher earlier in the season in the UNR crop (at 69 DAS) but there were no differences in total dry matter towards the end of the season (131 DAS)(Table 4).

The different morphology of the cluster line did not alter its light interception over the season and no advantage in terms of light interception or biomass development was observed in UNR cotton crop compared to the normal variety. The cluster line had a higher harvest index but this did not give the cluster fruit a yield advantage as the normal variety compensated by its larger size and production of more fruiting sites. This is typical of the trade off between earliness and yield.

Yield, Yield Components and Fiber Quality

There were no significant interactions between row spacing and variety for lint yield, mature boll size, number of mature bolls per meter, fiber length or micronaire (Table 5).

There were no significant differences in lint yield, number of bolls per meter or fiber quality between varieties (Table 5). Boll size was smaller in the cluster line compared to the normal variety a significant difference in gin turnout between the varieties may be the reason for no difference in lint yield.

There were no significant differences in lint yield, boll size, number of bolls per meter or fiber quality between the conventionally spaced and UNR cotton crop (Table 5). The increase in plant density in the UNR crop compensated for having fewer bolls per plant in the UNR crop resulting in similar numbers of bolls per unit area and comparable yield to the conventionally spaced crop.

In terms of yield and fiber quality there was no advantage to having a cluster line in the UNR cotton crop. In fact, the trend was for less relative yield of a cluster line under UNR (72%) than for a conventional variety (88%).

Conclusion

There were no significant benefits in yield, fiber quality or maturity using a cluster line in a UNR system. There were few interactions between the different plant types and row spacing. The interactions in this study were related to individual plant architecture and need to be further explored as the cluster line did not appear to respond as dramatically in terms of reduction in the number of nodes and fruiting positions on a per plant basis. Sicala 40 is a high yielding variety that had higher relative yield than the cluster line, which was earlier maturing in both row spacings. Further development of cluster lines that are equal to commercial lines may respond better to UNR row spacings.

Although the UNR cotton initially had greater light interception and intercepted more light over the growing season, this did not translate into differences final total dry matter, yield or earlier maturity. The shorter and more compact UNR plants produced fewer fruiting sites and mature fruit per plant. Although fewer fruit were produced per plant, the higher plant density resulted in there being no significant difference in fruit number per unit area. Retention was affected by row configuration with lower retention in the UNR crops compared to conventionally spaced cotton, which may have impacted on any maturity or yield benefits.

It is important to note these are the results of a one-season trial and the cluster line used had considerable variation in the length of fruiting internodes, possibly due to heterozygosity of the genes controlling this trait. A more uniform cluster line may perform better in a UNR system. Further research into the key physiological processes of UNR production is continuing in order to understand and optimise the system.

Acknowledgments

Thanks to Dr. Greg Constable for provision of seed and helpful discussion on the manuscript. Thanks also to Jane Caton, Daniel Kirk, Jo Price, Graeme Rapp and Suz Greig for assistance in the field. This work was partially funded by the Cotton Research and Development Corporation.

References

Bednarz, C.W., D.C. Bridges, and S.M. Brown. 2000. Analysis of Cotton Yield Stability Across Population Densities. Agronomy Journal 92:128-135.

Bourland, F.M., N.R. Benson, E.D. Vories, N.P. Tugwell, and D.M. Danforth. 2001. Measuring Maturity of Cotton of Using Nodes above White Flower. Journal of Cotton Science 5:1-8.

Constable, G.A. 1977. Narrow Row Cotton in the Namoi Valley 1. Growth, Yield and Quality of Four Cultivars. Australian Journal of Experimental Agriculture and Animal Husbandry 17:135-142.

Fowler, J.L., and L.L. Ray. 1977. Response of two cotton genotypes to five equidistant row spacing patterns. Agronomy Journal 69:733-738.

Galanopoulou-Sendouka, S., A. Sficas, N. Fotiadis, A. Gagianas, and P. Gerakis. 1980. Effect of population density, planting date, and genotype on plant growth and development of cotton. Agronomy Journal 72:347-353.

Heitholt, J.J., and J.M. Stewart. 1999. Cotton Genotypes Exhibiting Cluster-Like Fruiting Morphology and their Response to 30-inch Rows. p 640. *In* P. Dugger and D. Richter (ed.) 1999 Proceedings of the Beltwide Cotton Conferences. Jan 3-7. Orlando, FL. National Cotton Council. Memphis, TN.

Jost, P.H., and J.T. Cothren. 2000. Growth and Yield Comparisons of Cotton Planted in Conventional and Ultra-narrow Row Spacings. Crop Science 40:430-435.

Kerby, T.A., K.G. Cassman, and M. Keeley. 1990. Genotype and Plant Densities for Narrow-Row Cotton Systems. II. Leaf Area and Dry-Matter Partitioning. Crop Science 30:649-653.

Kerby, T.A., B.L. Weir, and M.P. Keeley. 1996. Narrow-Row Production, p. 356-364, *In* S. J. Hake, et al., Eds. Cotton Production Manual. University of California, Oakland.

Krieg, D.R. 1996. Physiological Aspects of Ultra Narrow Row Cotton Production. p 66. *In* Dugger and D. Richter (ed.) 1996 Proceedings of the Beltwide Cotton Conferences. Jan 9-12. Nashville, TN. National Cotton Council. Memphis, TN.

Lewis, H.L. 1971. What is narrow row high population cotton? The Cotton Ginners Journal and Yearbook. March 1971:49.

Wall, G.W., J.S. Amthor, and B.A. Kimball. 1994. COTCO2: a cotton growth simulation model for global change. Agricultural and Forestry Meteorology 70:289-342.

Table 1. Influence of row spacing and plant type on time to first square, first flower, 60% maturity, nodes above white flower (NAWF = 5), final height and number of mainstem nodes (DAS = days after sowing; *Significant difference in row spacing; †Significant difference in plant type; ‡Significant interaction between row spacing and plant type).

	Conventional		**UNR**	
Variable	**Cluster**	**Sicala 40**	**Cluster**	**Sicala 40**
Nodes to First Fruiting Branch	7.78†‡	9.12†‡	6.92†‡	9.50†‡
50% First Flower (DAS)	74.7*†	82.0	80.0*†	87.0*†
60% Mature Bolls (DAS)	146.7†	150.3†	143.7†	150.0†
NAWF = 5 (DAS)	104.3*	104.1*	100.6*	101.0*
Final Height (cm)	89*†	79*†	73*†	66*†
Final Nodes	20.2*†‡	24.8*†‡	19.1*†‡	19.8*†‡

Table 2. Influence of row spacing on individual plant architecture at maturity in terms of node to first fruiting branch, number of fruiting sites, number of mature fruit (open bolls), and fruit retention (*Significant difference in row spacing; † Significant difference in plant type; ‡Significant interaction between row spacing and plant type).

	Conventional		**UNR**	
Variable	**Cluster**	**Sicala 40**	**Cluster**	**Sicala 40**
Number of Fruiting Nodes	13.21*†‡	15.31*†‡	12.67*†‡	11.00*†‡
Number of Fruiting Sites per Plant	17.7*†‡	28.8*†‡	16.4*†‡	16.7*†‡
Number of Open Bolls per Plant	8.48*	10.21*	6.75*	4.83*
% Retention Overall per Plant	48.5*†	45.9*†	37.2*†	38.5*†
1^{st} Position Retention per Plant (%)	48.2*†	36.5*†	41.0*†	29.6*†
1^{st} Position Fruit (open bolls per plant)	6.42*	6.96*	4.75*	4.17*
2^{nd} Position Fruit (open bolls per plant)	1.82*‡	2.96*‡	1.75*‡	0.75*‡

Table 3. Canopy closure, radiation use efficiency (RUE) and cumulative intercepted solar radiation in different row spacings and plant types (DAS = days after sowing; *Significant difference in row spacing; †Significant difference in plant type).

	Conventional		**UNR**	
Variable	**Cluster**	**Sicala 40**	**Cluster**	**Sicala 40**
Canopy Closure (light interception 80% (DAS))	107.6*	98.0*	80.2*	76.6*
RUE (g/MJ) (69 DAS)	0.59*	0.75*	1.07*	0.97*
RUE (g/MJ) (131 DAS)	0.89	1.01	0.91	0.94
Cumulative Intercepted Solar Radiation at Maturity 160 DAS (MJ/m^2)	2242*	2303*	2418*	2461*

Table 4. Influence of row spacing and plant type on total dry matter (TDM) and harvest index (DAS = days after sowing; *Significant difference in row spacing; †Significant difference in plant type).

	Conventional		UNR	
Variable	**Cluster**	**Sicala 40**	**Cluster**	**Sicala 40**
TDM (g) (69 DAS)	115*	143*	230*	118*
TDM (g) (131 DAS)	1149	1698	1617	1715
Harvest Index (69 DAS)	0.0962†	0.0353†	0.1142†	0.0272†
Harvest Index (131 DAS)	0.685†	0.590†	0.680†	0.649†

Table 5. Influence of row spacing and plant type on lint yield, 60% maturity, size and number of bolls, fiber strength, fiber length and micronaire. (*Significant difference in row spacing; †Significant difference in plant type).

	Conventional		UNR	
Variable	**Cluster**	**Sicala 40**	**Cluster**	**Sicala 40**
Lint (bales/acre)	4.15	4.69	4.13	5.72
Boll Size (seed cotton, g/boll)	5.59†	6.49†	4.76†	5.85†
Bolls/m^2	100.7	93.1	110.0	126.0
Fiber Length (dec. inches)	1.16	1.13	1.16	1.10
Micronaire	4.17	4.23	4.17	4.2

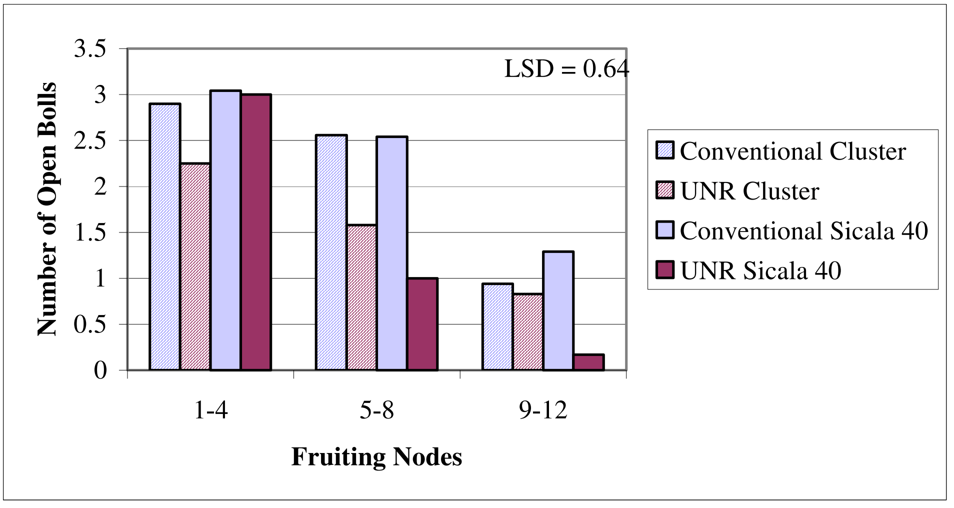

Figure 1. Number of open bolls on different fruiting nodes at the bottom (1-4 nodes), middle (5-8 nodes) and top (9-12 nodes) of plants grown in different row spacings and with different plant types at Narrabri, Australia 2002-2003.

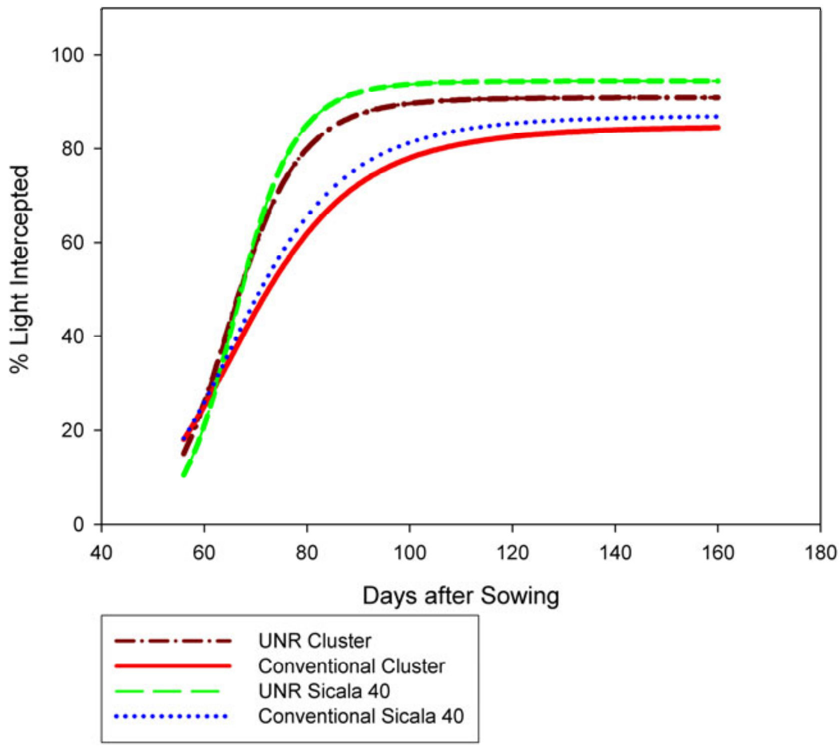

Figure 2. Average percentage of light intercepted by cotton grown with different plant types and in different row spacings over the 2002-2003 growing season, Narrabri, Australia.