Yield and quality evaluation of cotton cultivars grown under dryland conditions in summer dominant rainfall environments of Eastern Australia

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ABSTRACT

Dryland cotton has become an important component of Australian production, increasing from minor areas in 1990/91, to over 20% of the total area recently. It is clearly important to provide growers with accurate information on cultivar performance under dryland production systems. Since 1998 large scale dryland cultivar evaluation trials have been established at up to 13 locations each season, from Clermont (lat 22S) through to Breeza lat (32S). Although all of the cultivars tested were bred for high yield under irrigated conditions, some cultivars have proved to be well adapted to dryland production systems. There were clear yield and fiber quality differences between cultivars, indicating confident recommendations for dryland systems. Full season okra leaf cultivars were generally superior to other cultivar types.

Introduction

Dryland cotton is cultivated in the more favorable summer dominant rainfall environments of eastern Australia. Soil types that have high moisture holding capacity are essential for reliable production and there has been a strong trend toward zero tillage production systems over the past 10 years. In most seasons moderate to severe moisture stress will occur during the season and good levels of stored soil water is essential for reliable production.

Cultivars bred for irrigated production by the CSIRO have been used commercially by the dryland industry. A large-scale evaluation program carried out by Cotton Seed Distributor Ltd and CSIRO has evaluated a large number of cultivars over that time. This large-scale trialing program has identified several cultivars that have consistent yield and fiber quality advantages in the dryland environment.

Since 1997 CSIRO has had an active breeding and selection program for improved dryland cultivars. The first lines to partially originate from this new program were tested in the large-scale CSD trials during the 2000/2001 season. The commercial release of specific dryland adapted cultivars from this program is expected to occur over the next few years.

Experimental procedure

Field experiments have been located at up to 13 sites throughout northern NSW and Queensland over the past five seasons (Figure 1). A smaller number of experiments were carried out during the 10 years prior to 1997. All sites were planted, managed and harvested by the co-operating farmers. Plot sizes ranged from 0.27 to 2.4 ha using standard 1 meter row spacing, skip row and double skip row configurations, giving effective row spacings of 1, 1.5 and 2 meters respectively.

All experiments were laid out in either a replicated or repeated check design that was analyzed using nearest neighbor statistics to remove field variability. At harvest each plot was mechanically harvested and weighed using portable scales. A sample of seed cotton (5-10 kg) was taken and ginned using a small-scale (10 or 20 saw) gin. Lint yield (kg/ha) was determined by multiplying the lint percent by the seed cotton yield per hectare. Samples of lint from each cultivar were then tested for fiber quality using commercial High Volume Instrument (HVI) equipment.

Experimental site locations

Figure 1 shows the various experimental site locations. Clermont (22.8 S, 147.6 E) with an elevation of 267 m is the most northerly site and Breeza (30.9S, 150.2 E) with an elevation of 306 m is the most southerly site. The range of growing day degrees and rainfall is summarised in Table 1.

Soil types varied from at each experimental site but the majority of experiments were grown on vertisols with clay contents greater than 45%. Water holding capacity also varies depending in clay content and soil depth. Plant available water (PAWC) on the best soils of the Darling Downs in southern Queensland and Breeza on the Liverpool Plains exceeded 240 mm. PAWC on some soils in the Goondiwindi region are as low as 120 mm. The amount of soil water available is also a function of how much fallow rainfall is received and stored after the previous crop. A nine to 10 month zero-till fallow from a winter cereal crop is now the most favored and reliable way to store pre plant rainfall.

The Ozcot simulation model developed by the CSIRO (Commonwealth Scientific and Industrial Research Organisation) is computer model that simulates cotton growth. The model has been used to generate to generate yield variation at a number of the dryland sites using all available weather data. The model had been validated for irrigated and rainfed cotton production in south eastern Australia.

Results and Discussion

Conventional (non-transgenic) and transgenic (cultivars containing the Ingard® or Bollgard® gene from Monsanto) were evaluated.

Conventional cultivars

Across the 12 environments, yield levels ranged from 398 to 1502 kg lint/ha. On average, Siokra V-16 and Siokra 1-4 had significantly higher yield than all other cultivars (Table 2). Fiber length and micronaire did not differ between cultivars, however Siokra V-16 had significantly greater fiber strength than all other cultivars (Table 2).

Transgenic cultivars

The development and testing of transgenic cultivars for dryland conditions began after the commercial release of Ingard® in Australia in 1997. Table 3 summarizes the results of five Ingard® experiments grown between 1997 and 2000. Yield levels ranged from 570 to 1894 kg lint/ha. On average, Siokra V-15i had significantly greater yield and longer fiber than all other cultivars.

Yield variability

Table 4 details dryland yield variation using the 45 years of climatic data available for each site using the Ozcot simulation model developed by CSIRO. The model assumed the planting date to be the 1st of October at both sites and gave the same PAWC (200 mm) for each location. This simulation suggests that yield variation of over 700% at Clermont and 500% at Breeza can be expected across years. Table 5 compares the fiber quality of Sicot 80, Siokra V-16 and Siokra V-17 in water unlimited (irrigated) experiments with dryland sites. On average, all cultivars have fiber length above the price discount level. However, Siokra V-17, which inherently has the shortest fiber, often fell below the price discount level. Fiber length is particularly short at sites where the yield potential is low. A regression analysis of fiber length and yield indicates an increase of 0.56 mm per 25.4 mm (one inch) for every 227 kg/ha (one bale) increase in yield ($P \geq 0.05$).

Discussion

Analysis of the full data set (83 experiments) is difficult due to the rapid development and adoption of new cultivars. Obtaining an orthogonal data set has been achieved by dividing up the complete data set into smaller groups of trials with identical cultivars. However, this obviously limits the degrees of freedom in the analysis and reduces the likelihood of statistically significant differences in yield and quality parameters.

Season length varied considerably between the experimental sites. In general season length is longest in the North. At Clermont 3247 day degrees are accumulated from September to April, while at Breeza only 2349 day degrees are available. There is good planting date flexibility at Clermont but at Breeza the planting window is only about 40 days. The variability of growing conditions between sites and seasons is a considerable challenge to the consistent performance from any one cultivar.

Previous experiments described by Stiller *et al.* (2003) have indicated that, on average, full season cultivars perform best under dryland conditions in Australia. This generally agrees with the data presented in Table 2, with the early maturing cultivar Siokra S-101 having the lowest numerical yield. However, the medium maturing Siokra 1-4, together with the late maturing Siokra V-16 had statistically the highest yield. This indicates that other factors are involved other than maturity. Full season indeterminate types can maintain growth rates longer than quicker maturing cultivars experiencing moisture stress. Full season maturity also allows the crop to take greater advantage of in-crop rainfall events. This trend toward higher yield from full season cultivars is in contrast to dryland cultivars used in west Texas in the United States. In the High Plains environment a drought escape mechanism is utilized and early maturity escapes severe moisture stress. Specialist drought tolerant cultivars from the Texas breeding programs have failed to perform under Australian conditions.

Okra leaf cultivars such as Siokra V-16, Siokra 1-4 and Siokra V-15i have yielded significantly better than normal leaf cultivars at dryland sites (Tables 2 and 3). It has been documented that the okra leaf trait has greater photosynthesis per unit leaf area and higher WUE (Baker and Myhre, 1968; Pettigrew *et al.*, 1993). Our yield data (Tables 2 and 3) support the conclusion that the okra leaf trait was useful for dryland environments.

The impact of water stress on fiber quality is an important factor when selecting suitable dryland cultivars. Siokra V-16 and Sicot 80 are considered suitable for dryland production while Siokra V-17 represents a significant risk of producing fiber with a length below the Australian standard (27.4 mm). Reduced fiber length in dryland crops leads to significant loss of lint value. Only cultivars with genetically long fiber characteristics are suitable for the dryland production. Micronaire values of the conventional cultivars were not significantly different. Micronaire measured fiber maturity can be influenced by the environment and cultivar. Breeding programs have aimed to keep micronaire values within a range of 3.5 to 5.0. Differences in micronaire values between the transgenic cultivars reflect some diversity between the cultivars and a reduction in the impact insects on fiber maturity, resulting in higher micronaire. Conventional cultivars are normally subjected to enough insect damage to delay maturity and therefore reduce micronaire values.

Conclusions

At dryland environments in south eastern Australia full season cultivars produced the highest yields. Yield is highly variable and responsive to stored moisture and in crop rainfall. Full season maturity allows the plants to better capitalize on irregular rainfall events. In addition, okra leaf cultivars generally had higher lint yields in dryland environments. Fiber length is a critical property influenced by the environment and the cultivar. Several cultivars have inherently longer fiber and are the most suitable for dryland production.

References

- Baker, D.N. and Myhre, D.L. (1968). Leaf shape and photosynthetic potential in cotton J. M. Brown (ed.) Beltwide Cotton Prod. Res. Conf., Hot Springs, AR. 9-10 Jan. Natl Cotton Council of Am., Memphis TN, pp. 102-109
- Pettigrew, W.T., Heitholt, J.J. and Vaughn, K.C. (1993). Gas exchange differences and comparative anatomy among cotton leaf-type isolines. *Crop Sci.,* **33**: 1295-1299.
- Stiller, W.N., Reid, P.E. and Constable, G.A. (2003). Maturity and leaf shape as traits influencing cotton cultivar adaptation to dryland conditions. *Agronomy Journal* (in press)

Table 1. *Mean season (September – April) growing day degrees (base 12 °C) and rainfall for the range of dryland sites.*

Site	Growing day degrees	Rainfall (mm)
Clermont	3247	470
Goondiwindi	2733	421
Bongeen	2515	575
Croppa Creek	2633	509
Wee Waa	2596	458
Breeza	2349	451

Table 2. *Leaf type (O = okra, n = normal), maturity group (1 = early, 3 = late), lint yield, fiber length, fiber strength and fiber micronaire of five cultivars grown under dryland conditions at six sites over two seasons.*

Cultivar	Leaf type	Maturity group	Lint yield (kg/ha)	Fiber length (mm)	Fiber strength (g/tex)	Fiber micronaire
Siokra V-16	O	3	969	28.7	30.6	4.3
Siokra 1-4	O	2	951	28.3	28.8	4.2
Siokra S-101	O	1	821	28.3	29.4	4.1
Sicot 189	N	3	827	28.2	29.8	4.2
Delta Pearl	N	3	865	28.1	28.2	4.3
SED			38.9	0.26	0.45	0.09
			$P \leq 0.001$	NS	$P \leq 0.001$	NS

Table 3. *Transgenic Cultivars (1997-2000). Leaf type (O = okra, n = normal), maturity group (1 = early, 3 = late), lint yield, fiber length, fiber strength and fiber micronaire of 4 Ingard® cultivars grown under dryland conditions at five sites over three seasons.*

Cultivar	Leaf type	Maturity group	Lint yield (kg/ha)	Fiber length (mm)	Fiber strength (g/tex)	Fiber micronaire
Siokra V-15i	O	3	1223	28.7	29.1	4.5
Sicala V-2i	N	3	950	26.9	28.6	4.3
Sicot 189i	N	3	1075	27.4	29.7	4.4
NuCOTN 37	N	3	982	27.1	27.0	4.6
SED			99	0.52	0.46	0.10
			$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.001$	$P \leq 0.01$

Table 4. Yield data obtained from the Ozcot simulation model for Clermont and Breeza (Richards, personal communication).

Site	Max yield	Minimum yield	Mean Yield	Median Yield
Breeza	1632	293	849	737
Clermont	1911	256	906	819

Table 5. Impact of water stress on fiber quality of three cultivars, Sicot 80, Siokra V-16 and Siokra V-17. Data is the average of experiments over three seasons.

	Cultivar	Length (mm)	Strength (g/tex)	Micronaire
Irrigated	Sicot 80	29.5	30.3	4.3
Dryland	Sicot 80	28.4	31.9	4.7
Irrigated	Siokra V-16	30.0	31.5	4.0
Dryland	Siokra V-16	28.7	31.9	4.5
Irrigated	Siokra V-17	28.4	30.2	4.2
Dryland	Siokra V-17	27.7	29.5	4.4

Figure 1. Experimental site locations.