

BREEDING FOR IMPROVED WATER USE EFFICIENCY OF COTTON – A SUMMARY

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Abstract

A project examining ways of improving the water use efficiency of cotton through breeding has now been completed. This paper summarises the results of four years research. There was an interaction between cultivar and water environment, created by two okra leaf cultivars, Siokra L23 and Siokra 1-4 yielding relatively better under raingrown compared to irrigated. Cultivar maturity was highly correlated with raingrown yield and for each day increase in maturity yield increased by 34.4 kg/ha. Longer season cultivars had greater agronomic and leaf WUE than shorter season cultivars. This maturity, together with okra leaf produced the greatest WUE. Heritability of WUE traits in breeding populations was moderate to low and may still have some utility as selection criteria. A breeding strategy is presented which incorporates new techniques into the current breeding programme.

Introduction

The vast majority of cotton in Australia is still grown under irrigation. However, unreliable rainfall, debate over environmental river flows and restricted supply of irrigation water can limit production and contain expansion. Raingrown production has increased from minor areas ten years ago, to over 130,000 ha in northern NSW and Southern QLD in 1999/00.

Raingrown cotton plantings experience extended periods of water stress and consequently yields are variable. To improve performance, or create consistency of production between years, we need to know the major physiological and morphological traits associated with drought tolerance in order to know which traits may be utilised in a breeding programme. Some of the traits which have breeding potential include leaf conductance, osmotic adjustment, leaf water potential, root growth and soil water extraction, and heat and desiccation tolerance (Rosenow *et al.*, 1983).

There is existing technology to evaluate these traits. Some of the methods are simple, rapid and can be used to screen large numbers of plants, whereas others are complex and time consuming. In the past, plant breeders have made little use of these techniques to improve the raingrown performance of cotton. This project aimed to determine the utility of existing and new techniques in breeding improved raingrown cultivars.

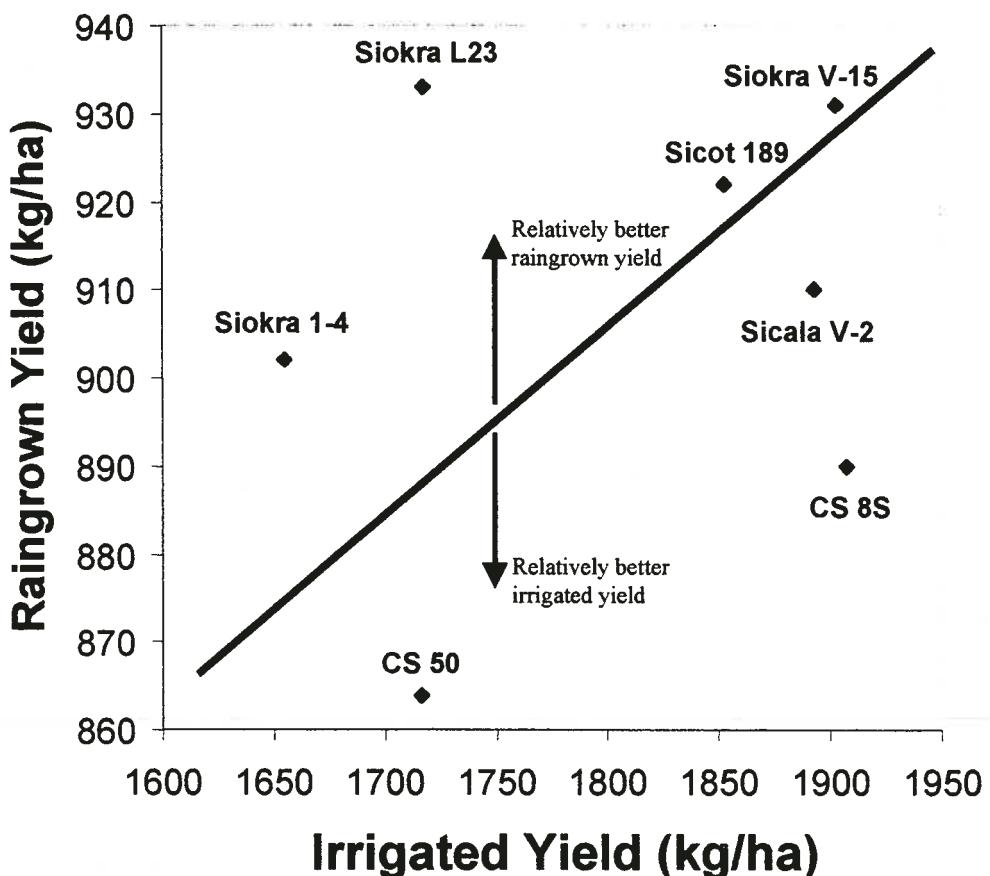
Result highlights

Yield

Data from three sites (Narrabri, Dalby and Biloela) over four seasons was used for a comprehensive analysis comparing raingrown and irrigated yields from small scale plots. On average, irrigated sites yielded 48% more and had 4% longer fibre than adjacent raingrown sites. Siokra L23 and Siokra 1-4 created a significant cultivar x water environment interaction. This indicates that these cultivars yielded relatively more under raingrown conditions than irrigated, compared to the other cultivars, particularly CS 8S and CS 50. Figure 1 describes this relationship. The cultivars that are above the line performed relatively better under raingrown compared to irrigated conditions and the cultivars that are below the line performed relatively better under irrigated compared to raingrown

conditions. The cultivars that are close to the line (Siokra V-15 and Sicot 189) performed relatively the same under both environments. There was however, a significant cultivar x site interaction which is hidden in Figure 1. This relates particularly to Sicot 189, which performed relatively well under raingrown conditions at Dalby, but less so at Narrabri and Biloela. The good result for this cultivar at Dalby increases its relative performance. Since this work commenced, Siokra V-16 has replaced V-15 and is 4-8 % higher yielding under both environments.

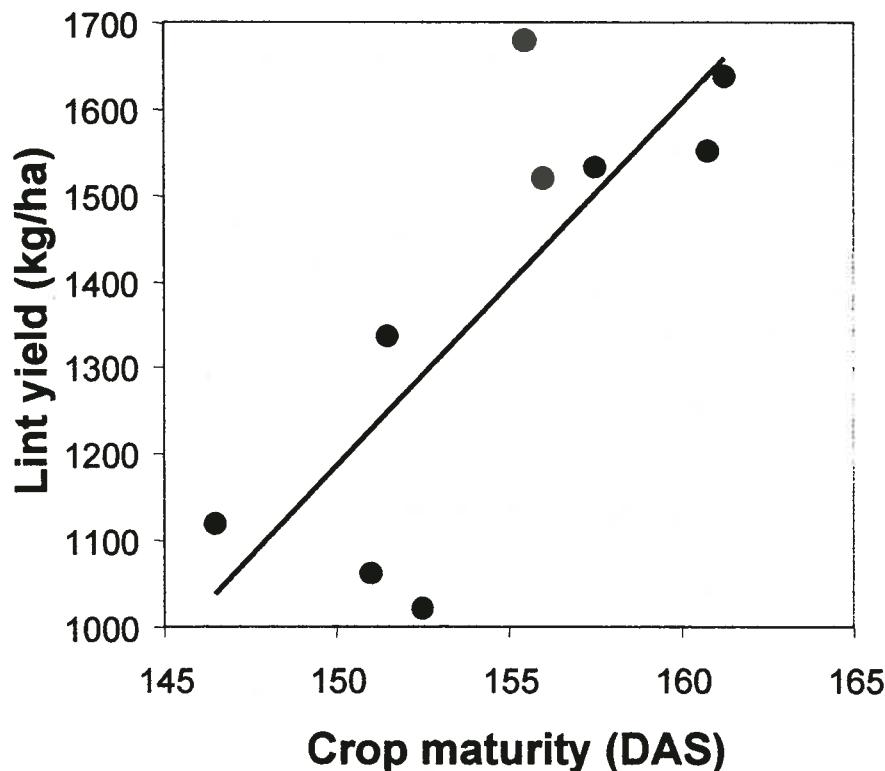
Figure 1: Association between irrigated and raingrown yield of seven cultivars averaged across three sites and four seasons.



Maturity

A second series of experiments compared Australian cultivars with early maturing Texan cultivars. On average, Australian cultivars were about 10 days later in maturity, had better fibre properties and yielded more than Texan cultivars. The most important association developed from these experiments is shown in Figure 2, the relationship between maturity and yield under raingrown conditions in Australia. Cultivar maturity explained about 70% of the variation in lint yield when data from all experiments were pooled. There was an increase in yield of 34.4 kg lint/ha for each day increase in maturity. This data is for normal planting times, and would not hold true for late plantings.

Figure 2: Association between lint yield and crop maturity (mean maturity date – days after sowing) for nine cultivars across four seasons.



Water use efficiency

Three cultivars were examined across four experiments for agronomic WUE (kg lint/ha/mm evapotranspiration). Compared with an early maturing Texan cultivar (Tamcot HQ95), a full season okra leaf cultivar (Siokra L23) extracted more water from deeper layers in the soil profile (data not shown) and had 20% greater agronomic WUE (Table 1). A full season normal leaf cultivar (Sicot 189) was intermediate for agronomic WUE. Gas exchange measurements were also carried out on the same cultivars to calculate leaf WUE. Trends in leaf WUE paralleled the trend in agronomic WUE, with Siokra L23 having the highest leaf WUE and Tamcot HQ95 the lowest. Again Sicot 189 was intermediate.

Table 1: Total water use, lint yield, agronomic WUE and leaf WUE of three cultivars averaged across four experiments.

Cultivar	Total water use (mm ET)	Yield (kg/ha)	Agronomic WUE (kg lint/ha/mm)	Leaf WUE ($\mu\text{mol CO}_2/\text{mol H}_2\text{O}$)
Tamcot HQ95	537	1214	2.26	45.3
Siokra L23	549	1549	2.82	53.8
Sicot 189	581	1483	2.55	48.0

Inheritance

Agronomic WUE cannot be measured in a breeding programme, due to the large number of lines required. It appears as though leaf WUE does give a reasonable indication of trends in agronomic WUE, so it was hoped to use this as a selection criteria. To examine whether leaf WUE would be of utility in a breeding programme, the inheritance (heritability) must be determined. Progeny of four crosses between Australian and Texan cultivars were evaluated in the F₂, F₃ and F₄ generations

for a range of gas exchange traits as well as carbon isotope discrimination (Δ). Selection was undertaken on the F_2 's for a combination of these traits, and the response measured in the F_3 and F_4 generations.

Heritability is measured on a scale of 0 to 1. A heritability of 0 means there will be no gain made by selecting for the trait, a heritability of 1 means large gains will be made by selecting for the trait. In these experiments lint yield had an average heritability of 0.26, on the moderate to low side. Heritability of leaf WUE was only 0.3, essentially no better than that for yield. It was concluded that although gains could be made through selection for leaf WUE, the techniques were too time consuming to use on large numbers of lines. Heritability of Δ was marginally better at 0.35. Measuring Δ is much easier and less time consuming than for gas exchange traits and it was concluded that there is merit in using Δ to screen some populations for WUE.

Breeding strategy and recommendations

From the experiments presented here, together with commercial experience, it was concluded that okra leaf and full season maturity are desirable traits of a raingrown cultivar for full season regions.

Gas exchange measurements used to calculate leaf WUE give an instantaneous assessment of the carbon fixation and water losses of a leaf. These measurements are not only time consuming, but are heavily influenced by the prevailing environmental conditions at the time of measurement, requiring complicated statistical procedures to remove unwanted trends in the data. For this reason, these type of measurements are not suitable to use in a breeding programme for measuring large numbers of individuals within segregating populations. They may, however, be useful in helping to determine genotypes to use as parents to create the required range of diversity for a particular set of traits. Genotypes with low Δ tended to have a higher yield under raingrown conditions. This gives rise to the possibility of incorporating Δ into the current breeding scheme, at the F_2 generation, and discarding individuals with higher Δ . The advantage would be gained by initially screening a greater number of individuals, potentially identifying a better performing line.

This research also suggested that an additional raingrown trial, sited in a raingrown production region not currently covered, may assist with producing more consistent raingrown cultivars.

Acknowledgements

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References

Rosenow, D. T., Quisenberry, J. E., Wendt, C. W., and Clark, L. E. (1983). Drought tolerant sorghum and cotton germplasm. *Agric. Water Manage.*, 7: 207-222.