Can planting date and cultivar selection improve resource use efficiency of Australian cotton systems?

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Abstract

Water is an increasingly valuable resource and there is uncertainty about future rainfall patterns in a changing climate. Similarly, there are concerns about nitrogenous fertiliser use due to risks of greenhouse gas emissions and rising costs. Hence, it is timely to revisit crop management strategies to determine if greater efficiencies can be attained and strategies developed to balance economic, social and environmental concerns. We investigated the potential to manipulate planting date to improve resource use efficiency and productivity in Australian cotton farming systems. Flexibility in planting date in some regions is now practical because transgenic Bt-cotton provides better insect control, resulting in higher fruit retention and a shorter fruiting cycle. This allows later plantings to maintain yield and fibre quality. A field experiment was conducted to investigate the effect of cultivar (differing in plant morphology) and delayed planting on productivity (yield and quality), and resource use efficiency (water and nitrogen). Results showed that cultivar and planting date significantly affected resource use efficiency and yield. Yield, and resource use efficiency was least for latest plantings while the middle planting date had the highest crop water and nitrogen use efficiency indicating some merit for considering this management strategy in regions with longer growing seasons. Simulation analyses using OZCOT confirmed these results.

Key words

Water use, Water use efficiency, Crop simulation, nitrogen

Introduction

Australian cotton growers have had access to transgenic insect tolerant cotton cultivars since 1996 which has resulted in a dramatic reduction in insecticide use by the industry (Knox et al. 2006). Transgenic Bt (Bollgard II?) cotton contains genes that express the insecticidal proteins Cry1Ac and Cry2Ab. Bollgard II controls major Lepidopteran pests of cotton (particularly Helicoverpa spp. in Australia) and as a consequence retention of squares (flower buds) and young bolls (fruit) is higher in these cultivars than non-Bollgard II cultivars (Wilson et al. 2004). Recent research has compared manipulating planting date of Bollgard II and non-Bollgard II cultivars to determine the effect on yield and quality (Bange et al. 2008). Results showed that delayed planting of Bollgard II cultivars did not compromise yield and improved fibre quality. Yield of non-Bollgard cultivars declined linearly with later planting dates. Bollgard II could be sown later as the same number of fruit to achieve yield could be produced in a shorter period of time due to improved insect control.

There is increasing competition for scarce water resources in many areas of the world. With the perception that irrigated cotton uses more water than other irrigated industries, irrigators need to increase their water use efficiency to maximise returns from this limited resource. Climate change and policy will also necessitate changes in management strategies for water and nitrogen use. With the advent of Bollgard II and the ability to change planting dates in long season cotton growing regions there maybe opportunities to refine management strategies to maximise these resources without compromising crop yield or product quality. This paper reports on field experiments investigating the impact of planting time and cultivar (differing growth habits and yield potential) on yield and water and nitrogen resource use efficiency and uses crop simulation (OZCOT, Hearn, 1994) to confirm outcomes.

Materials and methods

A field experiment was conducted in the 2008-2009 season at the Australian Cotton Research Institute (ACRI) at Narrabri, New South Wales (30^0 S, 150^0 E). The soil is classified as a grey Vertosol (Isbell, 1996). Three planting dates (25 Sept., 31 Oct. and 5 Dec.) and two cultivars (Sicot F1BRF, Sicot 70BRF) differing in morphology (Sicot F1BRF is taller, develops greater leaf area and is later maturing compared with Sicot 70BRF, G Constable pers. comm. 2010) and yield potential were evaluated. The normal planting date for Narrabri is 15 Oct. Cotton was planted 0.05 m deep in 1 m rows with 15 plants per metre. Plots were 8 rows by 17 m long. Weed and insect control was per standard recommendations for the Bollgard II cultivars planted. The experimental area was managed uniformly with respect to irrigation (70 mm deficit); with the exception that the third planting required two extra irrigations. Nitrogen was applied pre-plant (150 kg N/ha) to all plots. The experiment used a split-plot (main plots planting time, sub-plots cultivars) with three replicates.

Lint yield (kg/ha) was assessed by machine spindle harvesting one of the central 4 rows (13 May 2009) and sub-samples were taken for fibre quality analyses using Uster High Volume Instrument (HVI). In each plot a single neutron moisture meter access tube was installed to 1.2 m after crop emergence. Neutron moisture meter readings were undertaken (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 m depths) on a 10 day cycle and were also made prior to and 24 hr after each irrigation throughout the season. This enabled an estimate of crop water use. Soil samples were collected at the same depths prior to or post planting to determine starting soil water and repeated after harvest for finishing soil water. Rainfall was recorded from a local weather station located nearby. Crop water use (mm) was calculated from starting soil water minus finishing soil water plus in crop rain and irrigation. Plant samples were collected at cutout (end of new fruit development) for analysis of total nitrogen uptake to enable nitrogen use efficiency (kg lint per unit of nitrogen uptake by the crop) to be calculated. Water use efficiency (kg/ha/mm) was calculated as lint yield (kg/ha) divided by the season water use. Parameters were compared using ANOVA at the five percent level for significance (Genstat 12, Lawes Agricultural Trust, 2009).

To test the studies hypothesis in more than one season crop simulations using OZCOT were run from 1957 to 2005 using SILO patched point data with optimum inputs to determine the effect of later planting dates on crop water use and yield for Narrabri (long season cotton area).

Results

Late planting (5 Dec) significantly lowered yield of both cultivars with Sicot F1BRF more affected (Table 1). Season water use also reduced with this planting date but did not differ between cultivars (Table 1). Consequently there were no differences in WUE between the first two plantings for both cultivars, however in the last planting WUE was higher in Sicot 70BRF as a result of its lower water use combined with its higher yield (Table 1). Seasonal potential reference evapotranspiration (ETo) decreased with later planting date (1105 mm, 935 mm, and 750 mm for first, second and last plantings respectively) but was not correlated to increases in WUE in either cultivar. There was no significant difference in nitrogen use efficiency between planting dates or cultivars (Table 1).

To assess planting date on WUE simulation analyses with OZCOT were conducted. Results showed that for Narrabri (long season) there is a greater risk with an early plant date largely due to frost. For later sowings yield increased to 1 November. WUE also increased with later plantings and was due to both increased yield and lower seasonal evapotranspiration (Figure 1).

Table 1 Effect of planting date on lint yield (kg/ha), water use efficiency (kg/ha/mm) and season water use (mm) and nitrogen use efficiency (kg lint/kg N uptake) for Narrabri in 2008/09.

Planting date	Parameter	Cultivar

		Sicot F1BRF	Sicot 70BRF
25 Sept	Yield	2433^{a}	2428^{a}
	Water use	642^{1}	648^{1}
	Water use efficiency	3.8^{x}	4.1^{x}
	Nitrogen use efficiency	14.1^{A}	15.2^{A}
31 Oct	Yield	2475^{a}	2599^{b}
	Water use	621^{1}	635^{1}
	Water use efficiency	4.0^{x}	4.1^{x}
	Nitrogen use efficiency	13.9^{A}	14.5^{A}
5 Dec	Yield	1237^{d}	2078^{c}
	Water use	381^{2}	396^{2}
	Water use efficiency	3.2^{y}	5.3^{z}
	Nitrogen use efficiency	10.2^{A}	12.7^{A}

Numbers followed by the same superscript not significantly different

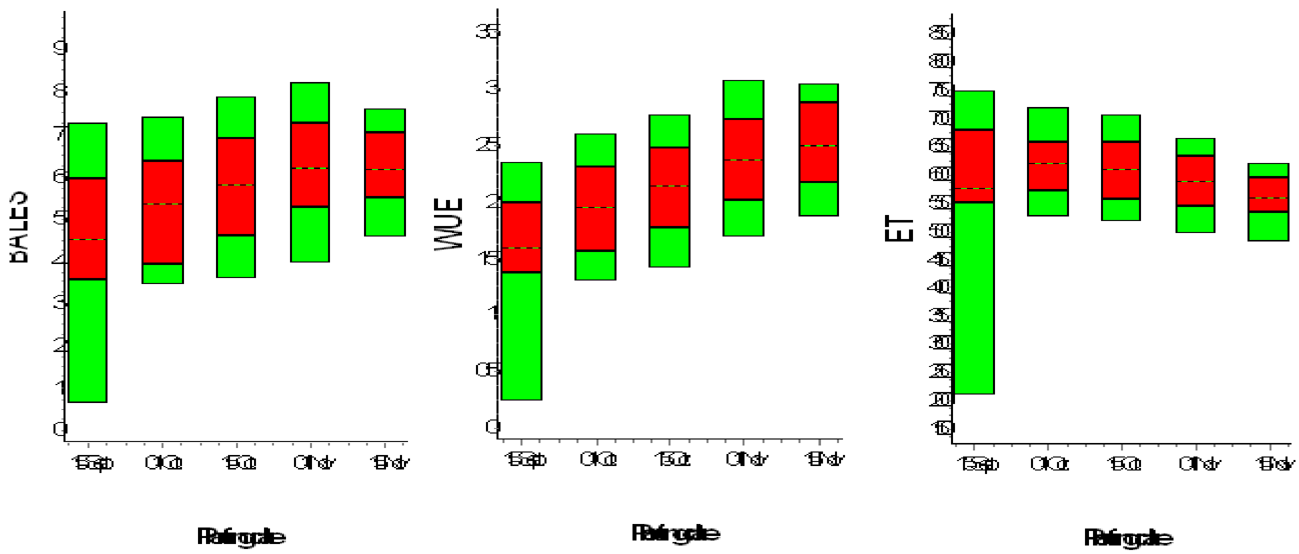

Figure 1 Effect of planting date on crop yield (bales/ha, 1 bale=227 kg lint), water use efficiency

(kg/ha/mm) and evapotranspiration (mm) for Narrabri (long season) determined using OZCOT crop simulation. (For each bar from the top down, the top is the 90 % percentile, the green-red interface is 75 % percentile, the solid line is the median, the dashed line the mean, the lower red-green interface is the 25 % percentile and the bottom is the 10 % percentile.

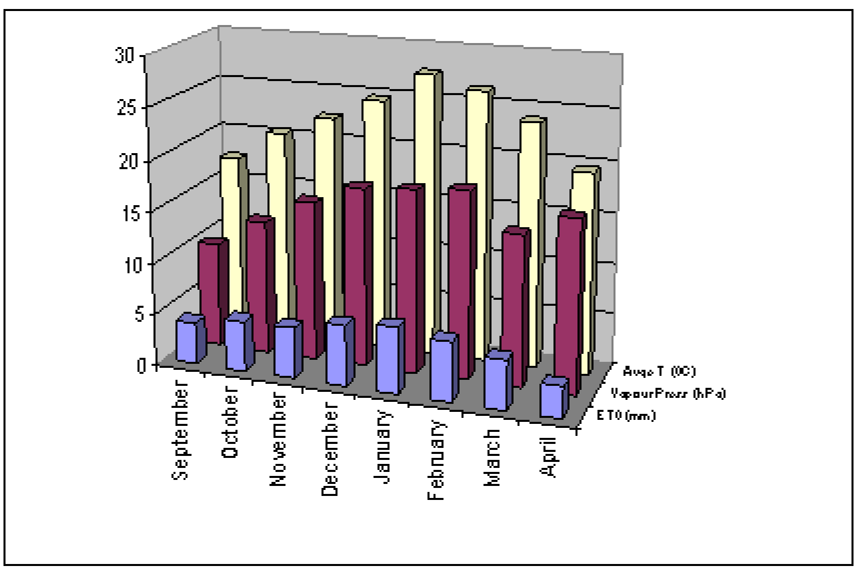

Figure 2 Average of the daily reference evapotranspiration (ETo (mm/day), vapour pressure (hPa) and average temperature (C) for each month of the Narrabri 08/09 cotton growing season.

Discussion

The aim of this work was to test the hypothesis that cotton cultivar choice and planting date may improve crop resource use efficiency, and will not compromise cotton yield and fibre quality. The field experiment confirmed previous research that later planting (a delay of 7 to 14 days after 15 Oct for long season cotton regions in Australia) with Bollgard II cultivars will not necessarily reduce yield in long season cotton growing regions. Cotton yield with the very late planting was significantly reduced due to the season length being shorter, which agrees with the results of Bange et al. (2008). This also explains the reduction in seasonal evapotranspiration.

In this study, with the exception of the latest planting date, water use efficiency was unaffected and was not related to potential average daily reference evapotranspiration. Simulation analyses for Narrabri however, showed that WUE of cotton crops could be improved with later planting, and that the improvements in WUE are associated with improved or similar yields and use water less. Like the field experiment the very late planting dates also had lower yields and water use. It is most likely that the reason for seasonal water use being less with later plantings is because the period of maximum crop growth rates and water use is being shifted into parts of the season that on average have lower atmospheric evaporative demand; i. e. from early January into February (Figure 2). Simulation analyses for short season regions (e.g. Hillston) showed that there was however, less opportunity to delay planting without large effects on yield and water use efficiency (data not presented).

The mean water use efficiency across both cultivars was 4.08 kg/ha/mm, which is double that reported by Tennakoon and Milroy (2003) as the industry average at that time. An industry wide survey in 2006/07 found a mean water use efficiency of 3.5 kg/ha/mm (Williams and Montgomery, 2008), which was greater than the previous survey, but lower than that reported here. Water use efficiency ranges of 6.2 to 3.6 kg/ha/mm have been reported under subsurface drip and furrow irrigation at Emerald (Bhattarai et al. 2003). These values are comparable to those measured in these experiments, although climatic conditions and cultivars varied.

Nitrogen use efficiency was less in the latest planting of the field experiment but fell within the optimal range suggested by Rochester (2007). The late plant date may have had access to nitrogen as the plant required it during early development but potentially more nitrogen remained in the soil due to the later planting date truncating the end of the season

Conclusions

This field experiment and crop simulation analysis showed that resource use efficiencies (water and nitrogen) were unaffected by later planting dates but can be affected by cultivar. Only very late plantings resulted in low yields substantially reducing crop efficiencies. The simulation analysis highlighted the opportunity to improve crop water use efficiency in long season areas with later planting as the period of maximum crop growth and water use will occur when there is lower atmospheric evaporative demand. Further research is investigating this opportunity for a greater number of seasons and regions.

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