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Irrigated cotton in the tropical dry season. III: Impact of temperature, cultivar and sowing date on fibre quality

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ABSTRACT

Depending on sowing month, temperatures during boll growth in the tropical dry season are potentially sub- or supra optimal for the fibre quality parameters length and strength. The aims of this research were to: (1) measure the effect of sowing date on the quality of fibre from cotton grown during the dry season as this was not known; (2) use the range in temperature created by varying sowing date in the dry season, to derive relationships with gin turnout, the fibre quality parameters length, strength and micronaire. Over three seasons, two *Gossypium hirsutum* (upland) cultivars and one *Gossypium barbadense* cultivar were sown from March to June at the Ord River (15.5°S), Western Australia. For the highest yielding sowing months of March and April, fibre length and strength were at or below market preference due to relatively low temperatures and solar radiation during early fibre development. Fibre micronaire achieved market preference at all sowing months due to favourable late season temperatures and radiation. It is likely that current *G. barbadense* cultivars will have short fibre when grown in the dry season. For fibre length and gin turnout quadratic responses ($p < 0.05$) to weighted minimum temperature were fitted for each cultivar, where the optimum minimum temperature was 18–20 and 16–17 °C, respectively. The cultivar differences in fibre properties observed here suggest that wider screening may identify *G. hirsutum* cultivars with suitable fibre length and strength in the dry season. It was demonstrated by weighting of temperatures for the contribution of the cohort of bolls pollinated each day; the variation in crop fibre quality and gin turnout in the field due to temperature can be predicted.

1. Introduction

Cotton is primarily grown for its fibre and the research reported here forms part of a broader research effort to evaluate the potential to grow cotton as an irrigated dry (winter) season crop in the Ord River Irrigation Area in Western Australia (15°S) and potentially more widely within the semi-arid tropics (Yeates et al., 2010a,b). This paper assesses the effect of cultivar, sowing month and temperature on fibre quality as the fibre quality of irrigated cotton grown in the tropical dry season was largely unknown.

Our previous research (Yeates et al., 2010a,b) found sowing in March and April produced the highest cotton lint yields which were comparable to the upper end of Australian and international benchmarks for irrigated cotton. However, high yield was correlated with bolls on the outside fruiting sites on the plant, which differed from temperate climates (approximately 30° lat.). Gin turnout was also affected by sowing date and possibly temperature. For the highest yielding March and April sowing months, biomass and canopy development were not limiting to yield, although the final biomass was accumulated via a slower maximum growth rate that was maintained for a longer period than occurs in temperate regions. Radiation use efficiency from first square to first flower was reduced in proportion to temperature which may limit dry weight accumulation in cooler than average seasons.

In the previous papers we also reported the daily minimum temperatures during boll growth for the March and April sowing months averaged 13–16 °C with the lowest individual minimum being 7.1 °C. Maxima and minima greater than 37 and 22 °C occurred during boll growth of the May and June sowings (Yeates et al., 2010a,b). These temperatures were consistent with the long term average (Cook and Russell, 1983) and could be problematic

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for fibre growth and development as fibre length, strength and micronaire are all affected by extremes of temperature (Gipson and Joham, 1968, 1969; Hesketh and Low, 1968; Gipson and Ray, 1970; Quisenberry and Kohel, 1975; Wanjura and Barker, 1985; Xie et al., 1993; Liakatas et al., 1998). The range of temperatures observed in the sowing dates used in these experiments also provide an opportunity to measure the effect of temperature on fibre quality for field grown cotton in an environment where average monthly radiation, although lower than temperate latitudes at the same growth stage, is reasonably constant during flowering, 19–22 MJ/m^2 (Yeates et al., 2010a,b).

The reported responses of fibre length to temperature have varied, being parabolic or linear to night or mean or daily range of temperature (Gipson and Joham, 1968, 1969; Hesketh and Low, 1968; Gipson and Ray, 1970; Wanjura and Barker, 1985; Liakatas et al., 1998). Large cultivar differences in the type of response and sensitivity of fibre length to temperature have been measured (Hesketh and Low, 1968; Kohel et al., 1974). Fibre strength and micronaire are also reduced by cool temperatures (Gipson and Joham, 1968, 1969; Hesketh and Low, 1968; Gipson and Ray, 1970; Quisenberry and Kohel, 1975; Wanjura and Barker, 1985; Liakatas et al., 1998).

Fibre length is determined during the fibre elongation phase which occurs during the first 25–40% of the boll period (Schubert et al., 1973; Kohel et al., 1974; Thacker et al., 1989). Fibre strength and micronaire are determined toward the end of the fibre elongation phase and into the secondary wall formation phase, with most fibre weight increase occurring between 25 and 75% of the boll period (Schubert et al., 1973).

Due to cotton's prolonged flowering period, the final quality of a crop of cotton, in the absence of water and nutrient stress, is the sum of the contribution of cohorts of bolls that flowered on each day, thus have grown under different temperatures (Wanjura and Barker, 1985; Bradow et al., 1997). Hence, the prediction (simulation) of the effect of temperature on fibre quality for a crop of cotton requires a model that can predict the timing of the temperature sensitive boll development stages, the fibre quality and the proportion of lint yield contributed by each cohort of bolls.

Therefore, the aims of this paper are: first, to measure the quality of fibre from cotton cultivars grown during the tropical dry season. Second, to use the variation in temperature created by varying sowing date in the dry season, to derive relationships with gin turnout and the fibre quality parameters length, strength and micronaire.

2. Materials and methods

Sowing date by cultivar experiments conducted over three seasons at the Frank Wise Institute, 13 km NW of Kununurra, WA, Australia (15°39′S, 128°43′E) in the Ord River Irrigation Area were used to collect relevant data. These experiments are described in greater detail in Yeates et al. (2010a). To summarise, the *Gossypium barbadense* L. cultivar Pima S7 was compared with two Bt transgenic *Gossypium hirsutum* L. (upland) cultivars Siokra L23i and Sicot 50i (producing the Monsanto Cry1Ac protein). In the first season the non-Bt transgenic equivalent (Siokra L23 and CS50) of the upland cultivars were sown. Where data is combined for the three seasons these cultivars are referred to as L23 and S50. In each of the three seasons these cultivars were sown on four occasions (main plots): 27–29 March, 21–29 April, 15–23 May and 9–14 June; there were four replications. The experiments were furrow-irrigated. The crop was sown at a 90 cm row spacing on wide beds accommodating two rows per bed. Plots were six rows wide and 20 m in length. Analysis of variance was made using Genstat (Lawes Agricultural Trust, IACR, Rothamsted, UK) and regression analysis using SAS (SAS, 2001).

2.1. Measurements

Fibre quality was tested on a 300 g sub-sample of lint from each plot, with High Volume Instrumentation at CSIRO Plant Industry at Narrabri, NSW. Flower and boll counts were made from 1 m^2 in each plot at 10–14-day intervals from first flower to when 60% of bolls were open. A flower was defined as a boll when the petal was red. Gin turnout was measured as described in paper I (Yeates et al., 2010a). Because different gins were used over the three seasons the gin turnout relative to the maximum for each season was calculated for each cultivar and used in regressions with temperature. Temperatures were collected in a standard Stevenson screen 500 m from the experiment site.

2.1.1. Prediction of fibre quality from temperature

The objective of this analysis was to find out whether crop fibre length, strength, micronaire and gin turnout could be related to temperature for a field grown crop via the sum of contribution to the fibre properties of the bolls set each day of the flowering period. Where the number of bolls set each day is a cohort. Because the quality of each cohort was not measured (cost) the crop fibre quality (all cohorts combined) was related to a weighted temperature derived for each cultivar based on the proportional contribution to final boll number from each cohort. The method of calculation of weighted temperature was similar to that used by Yeates et al. (2000) to weight the effect of rainfall and humidity to predict seed quality of mungbean (*Vigna radiata*) using daily cohorts of ripe pods.

2.2. Steps in the calculation of weighted temperature

(1) *The proportion of final boll number (pollinated) per cohort*: This equals the daily increase in boll numbers (m^{-2}) divided by the total number of bolls set (m^{-2}) and was calculated from Fig. 1 for each cultivar and sowing month. For most of the treatments the increase in boll numbers from first flowering to the final value was linear (Fig. 1) and reflects the increase in boll dry weight, which was also linear from first flower (Yeates et al., 2010b). The last effective flower date occurred when final cohort of bolls pollinated, which was defined as the date when the boll count first reached the total at maturity. As Fig. 1 shows the count often increased after this date only to fall by crop maturity, hence it was assumed these additional bolls had been shed due to insufficient assimilate supply (see Hearn, 1994).

(2) *The boll period for each cohort*: The functions developed in Yeates et al. (2010a) were used:

Upland cultivars	$1/\text{bp} = 0.00122\ T_{\text{av}} - 0.0165$
Pima S7	$1/\text{bp} = 0.00124\ T_{\text{av}} - 0.0181$

where boll period (bp) is calculated by integrating the daily rate of progress to boll maturity (1/dp) due to average daily temperature (T_{av}).

(3) *The average temperature for different proportions of the boll period for each cohort*: The average minimum, mean and maximum daily temperatures for 30, 30–75, 75 and 100% of the boll period were calculated for each day of the flowering period.

(4) *The weighted temperature*: This was calculated from first flower to last effective flower and incorporated the proportional contribution of each cohort as shown:

$$\text{WT} = \sum_{\text{F}}^{\text{CO}} (T \times \text{boll number of each cohort/total boll number}).$$

where WT = weighed temperature; T = average temperature (maximum or minimum or mean) over the boll period, or