

Fruit production rates in cotton cultivars of different maturity times

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ABSTRACT

In cotton, the rate of production of new fruit decreases as the fruit (boll) load on the plant increases, eventually ceasing when the growth rate of the bolls is approximately equivalent to the growth rate of the whole plant. It is thought that the growing fruit monopolise resources within the plant and limit production of new fruit. We planted a short and a long season cultivar in the field on a number of dates and monitored their fruiting dynamics and growth rate to see whether there was any difference in the way fruiting responded to the carbon status of the plant. Initially, when there was no boll load to inhibit fruit production, the early maturing cultivar had a higher rate of fruit production than the late maturing cultivar. As the boll load developed and the amount of dry matter available for continued fruiting was limited, the impact on fruit production appeared to be similar for the two cultivars.

KEYWORDS

Cotton; dry matter partitioning; fruit production; *Gossypium hirsutum*.

INTRODUCTION

To be able to simulate the growth and development of cotton cultivars of differing maturity length, we need to identify parameters that differ between cultivars of contrasting maturity. Cotton is an indeterminate species. The timing of crop maturity is not governed solely by temperature and photoperiod. Rather, according to the nutritional hypothesis, the timing of crop maturity is determined by when the fruit that are already growing monopolise resources and prevent the crop from producing new fruiting sites (3). Usually, the crop then finishes maturing the fruit that are already set. Crop maturity can therefore be affected by variation in either the supply of resources to the fruit or by the demand the fruit are generating by their number or growth rate.

Recent work (1) has shown that a short and a long season cultivar did not differ in total dry matter production but early in reproductive growth, the shorter season cultivar produced fruit more rapidly and partitioned a higher proportion of dry matter to fruit. It was not possible however, to identify whether the higher reproductive partitioning was caused of the more rapid fruiting or a result of it.

In this paper we aim to determine (i) whether the cultivars differ in their potential rate of fruit production and (ii) whether they differ in their ability to support a given rate of fruit production for a given level of carbon supply. To examine the rate of potential fruit production we compared fruiting site production before the onset of negative feedback by reproductive development. We then examined whether the cultivars differed in their rate of site production for a given amount of dry matter to support fruit production.

Both cultivars were sown on a number of occasions, to generate different growth rates and fruiting patterns, and grown in the field under full irrigation with excellent nutrition and pest control.

MATERIALS AND METHODS

Cultural details

Two field experiments were conducted at the Australian Cotton Research Institute (ACRI) Narrabri, New South Wales. The experiments included a range of sowing times so as to span a range of temperature and radiation regimes, which in turn would influence dry matter production and fruiting patterns. Two okra

leaf cultivars, Siokra S324 and Siokra L22 (hereafter S324 and L22), were used (S324 represents the earliest maturing cultivars currently in commercial use in Australia and it is used for late times of sowing or in shorter season areas). L22 is later maturing and is suitable for longer, hotter growing areas. These cultivars represent the range of maturity types used in Australia, although earlier maturing types than S324 are available in other countries.

The first experiment (Exp. 1) consisted of three sowing times and two genotypes arranged factorially. Plots (4 m by 75 m), containing four rows spaced at 1 m, were sown on 10 October (S1), 20 November (S2) and 5 December 1995 (S3). A completely randomised design was used with four replications. The second experiment (Exp. 2) consisted of two sowing times with two genotypes arranged factorially. Plots (8 m by 20 m), containing eight rows spaced at 1 m, were sown on 11 October (S1) and 13 November (S2) 1996. For this experiment a randomised complete block design was used with four replications.

Measurements

Starting just before first square (flower bud) plant samples (1 m^2) were taken approximately every two weeks and partitioned into leaf, stem, and fruit to determine their mass in dry matter. To account for the high cost of synthesis of cotton fruit relative to vegetative tissue, biomass of all components was converted to glucose equivalents using production values (g glucose per g dry matter) from Wall et al. (7) for cotton leaves, stems, squares and bolls. Vegetative dry matter (VDM_g) was calculated from the difference between glucose adjusted total shoot dry matter and total fruit dry matter.

To measure the rate of production of fruiting sites (hereafter sites), three plants in each plot were monitored three times a week. It was possible to estimate accurately the date of events occurring on intermediate days. The appearance of a square (which determines a new site) was defined as the date when the subtending leaf unfolded (2). Site production was measured from the appearance of first square till harvest maturity. In Exp.1 site production was only measured after the appearance of first flower.

The number of sites produced over time shows a quadratic increase during early reproductive development (4). The site production rate before the onset of flowering was therefore determined from the slope of the regression of the square root of the cumulative number of sites against time in days.

The production of new sites in cotton is dependent on vegetative growth; indeed it is morphologically linked to the production of new nodes and leaves (5). As the growing bolls consume more of the available resources, the amount available for vegetative growth, and hence new site production, declines. It is possible that the cultivars differed in their decline in site production with the decline in the amount of dry matter available for vegetative growth. We therefore plotted the rate of sites per day between consecutive harvests against the rate of increase in VDM_g over the same interval.

RESULTS

Initial rates of site production

In Exp. 2 the rate of site production ($\text{sites}^{0.5} \text{ d}^{-1}$) before the onset of flowering between cultivars S324 and L22 was compared using linear stepwise regression analysis. When the two sowings of Exp. 2 were analysed individually, the inclusion of the cultivar as a factor in the regression of the rate of site production versus days after first square was significant ($P < 0.001$). In both sowings L22 had a lower rate of site production (Fig. 1). The slope of the regressions were 0.128 ($?0.005$) for S324, 0.086 ($?0.004$) for L22 in S1, and 0.120 ($?0.003$) for S324, 0.102 ($?0.003$) for L22 in S2. Thus on average S324 had a 32% higher rate of site production.

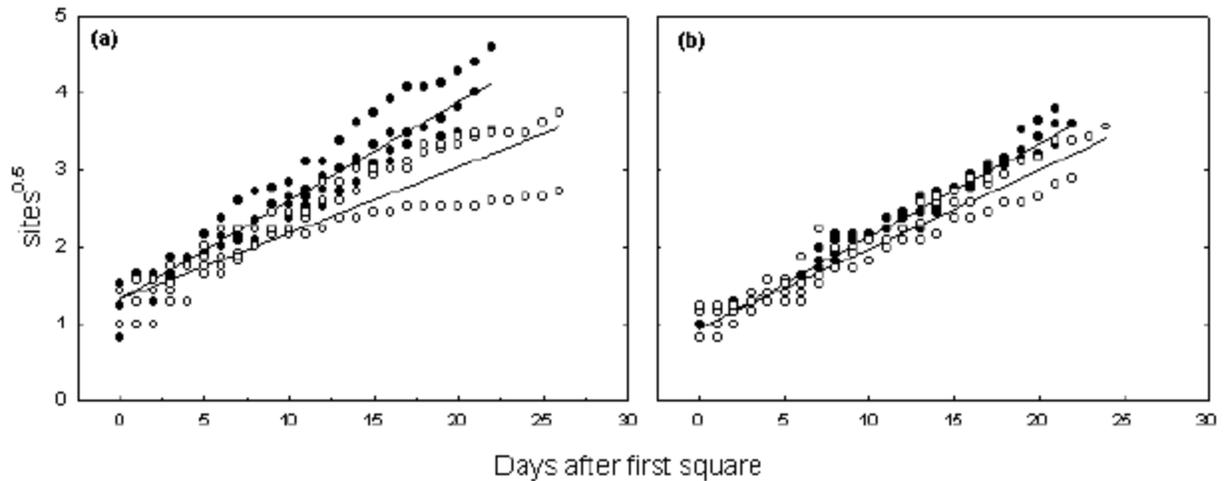


Figure 1. Fruiting site production versus days after first square until the onset of flowering in Experiment 2 (a) sowing 1 and (b) sowing 2 for cultivars S324 (closed symbols) and L22 (open symbols). The slopes of the regressions represent the rate of early site production.

Carbon status and site production

Figure 2 presents examples of fitted curves of the general responses of site production rate and the rate of change of VDM_g for the first sowing of experiment 2. Site production rate increased rapidly in both cultivars reaching a peak at approximately 70 days after sowing then declined rapidly. Cultivar S324 had a far higher rate of site production (Fig. 2a). Similarly the rate of change in VDM_g increased during early growth and reached a peak approximately 90 days after sowing then also declined rapidly. The rate of decline was far greater in cultivar S324 than for L22 (Fig.2b).

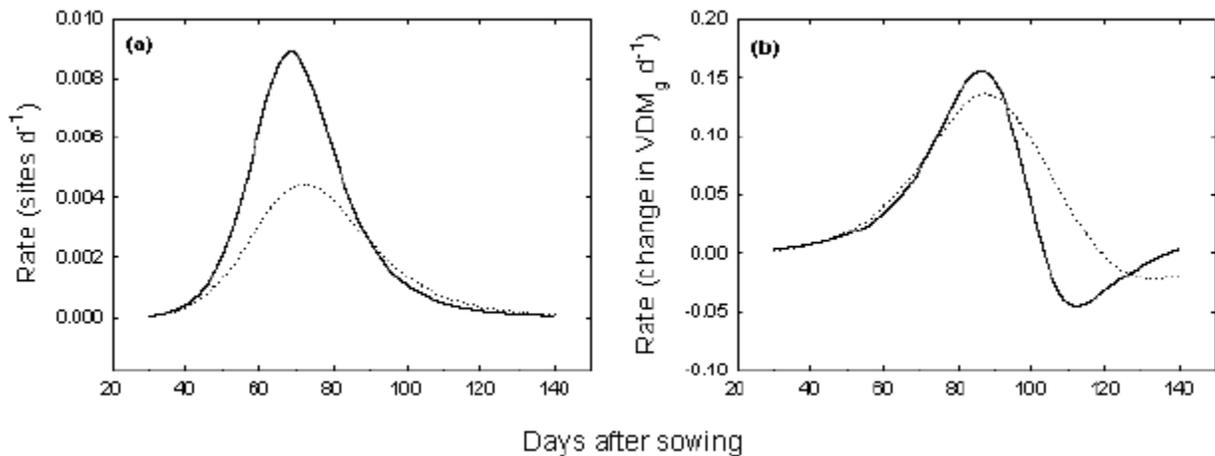


Figure 2. Dynamics of site production rate and rate of change in vegetative dry matter production for sowing 1 of experiment 2. Solid line is cultivar S324 and dotted line is cultivar L22.

Carbon status and site production

To compare the relationship between internal carbon status and site production, the raw data for site production rate following flowering was plotted against the rate of change in vegetative dry matter (VDM_g). Increases in the rate of vegetative growth rate during reproductive development mean that there

is more capacity for sites being produced. This relationship is expected for cotton because the production of sites is morphologically linked to vegetative growth (5); new vegetative growth produces sites.

When the rate of site production was plotted against the rate of increase in VDM_g no single relationship was apparent (Fig. 3). Rather, the data are scattered below an apparent envelope curve showing a decline in site production with declining VDM_g . There was no difference between the cultivars either when each sowing or experiment was examined individually (data not shown) or with all the data combined (Fig. 3).

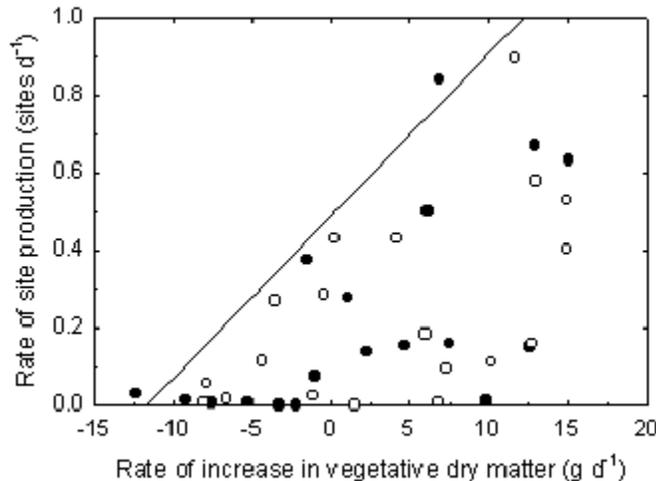


Figure 3. Rate of fruiting site production versus rate of vegetative dry matter production (VDM_g) during reproductive development. Cultivars S324 (closed symbols) and L22 (open symbols).

DISCUSSION

We previously showed that the cultivar S324 accumulated squares more quickly than L22. This was translated into an earlier development of green and finally open bolls (1). However, the pattern of increase in the number of squares could have been influenced by either the rate of site production or the rate of early shedding. Fig. 1 shows that the cultivars differed in their initial rate of site production. Prior to the setting of any fruit load, the earlier cultivar S324 produced sites quicker than the later maturing L22.

Our earlier analysis also showed that the two cultivars did not differ significantly in their ability to intercept light or translate this into total dry matter but S324 did show a markedly greater distribution of dry matter to the fruit during the period up to peak green boll number (1). Consistent with this, Pace et al. (6) found that when ^{14}C was applied to the uppermost mainstem leaf during early growth, an early cultivar partitioned a greater proportion of labelled C into reproductive structures than did a later maturing cultivar. It was not possible to conclude whether the earlier fruit production was driving the greater proportion of DM going to the fruit or whether the greater distribution to the fruit was allowing a higher site production rate. However, Fig. 3 shows that as the supply of carbon in excess of the demand by the developing fruit became limiting, there was no difference between the cultivars in terms of their ability to continue to produce new sites. That is there was no apparent difference in the cultivars ability to utilise available dry matter during reproductive development for site production. The scatter of points below the apparent envelope curve may be due to a number of reasons. Initially, at the onset of reproductive development, site production rates increased rapidly and vegetative dry matter production was low. This means the points lie close to the line. When the rate of site production began to decrease, vegetative growth rate was high and thus the points fell away from the line. In addition to this, the fact that the vegetative organs continue to grow after a site is produced means that the pattern of VDM_g production lagged behind the pattern of site production. In the example from Fig.1 there was a 20-day lag between peak site production and peak rate of change in VDM_g .

Therefore it would seem unlikely that the greater rate of fruit production for cultivar S324 is due to the fact that the development of a site required less dry matter, enabling more sites to be produced. Rather it is likely that the greater partitioning of dry matter to reproductive development in S324 is a consequence of higher rate of site production that was then translated into bolls. To test this hypothesis, studies are being conducted to assess the impact of manipulating carbon supply on the rate of site production. In addition we are continuing our analysis of assessing whether cultivars differ in their rate of shedding in response to carbon status.

CONCLUSION

Past research (1) showed that the short season cultivar (S324) and the long season cultivar (L22) had similar RUE but differed in dry matter partitioning to reproductive growth. In this paper we show that S324 had the higher initial site production rate. As there appeared to be no difference in the way site production responded to VDMg we conclude that the higher site production rate in S324, which resulted in the more rapid increase in boll load, would cause the earlier termination of site production. Manipulative experiments are being conducted to test this hypothesis.

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