

VARIETAL DIFFERENCES IN COTTON DEVELOPMENT: IMPLICATIONS FOR CROP MODELLING

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Summary: Simulations were run to test the sensitivity of OZCOT to varietal differences in developmental characteristics known to influence fruiting dynamics in cotton. Thirty one years of historical weather data from Myall Vale were used. The results indicate that the model is responsive to varietal differences over the actual range measured in two field experiments; both in terms of yield and time to 60% bolls open. Simulated changes in time to 60% bolls open were consistent with experimental evidence. It is therefore necessary to allow for these differences as inputs to the model and to measure the developmental characteristics for new cultivars to keep the model relevant to current production practices.

Introduction

In the OZCOT (Hearn 1994) and CERCOT cotton crop models developed by CSIRO at the Cotton Research Unit, allowance is made for varietal differences in boll size, lint percentage and some differences relating to the carbon balance of the crop. However it is known that cultivars also differ in developmental characteristics which govern their fruiting patterns. This in turn may alter their response to environmental stresses and insect damage. Of traits of this kind only the rate of square production is changed for the different varieties. In this paper we describe two field experiments designed to determine the natural variation between cultivars in four parameters used in the fruiting dynamics sub-model which is common to both the crop models: the time from sowing to first square, the time from appearance of an individual square to when it flowers (square period), the time from when a flower opens to when the boll opens (boll period), and the rate of

square production. We then used the observed range for these parameters in simulations conducted using OZCOT to assess the sensitivity of the model to them (in terms of yield and time to 60% bolls open) as an indication of their usefulness in describing the growth of different cotton varieties.

The Experiments

The field trials have been previously described (Wells 1992). Briefly, two time of sowing trials were conducted in 1990-91 and 1991-92 at the Narrabri Agricultural Research Station (NARS). Eight cultivars were sown at five times in each year. The cultivars used were Siokra 1-4, Siokra S324, Siokra L22, Sicala 33, Sicala V1, CS 189, CS 6S and Deltapine 90. The sowing dates ranged between 24 September and 4 December in 1990 and 24 September and 20 December in 1991. The experiments were fully irrigated and received 150kg ha⁻¹ of N. Standard pest and weed control were used.

The time from sowing to first square and square period were expressed in degree days using a base temperature of 12°C (DD₁₂). Boll period is expressed as an exponential function of the average temperature during boll development:

$$\text{Boll period} = \exp(a + m * T_{av}) \quad (1)$$

where T_{av} is the average temperature in °C and a and m are empirically derived parameters (Wanjura and Barker 1985, Constable 1991).

The squaring rate was characterised by the squaring constant: the square root of the rate of site production in thermal time (Hearn and Da Roza 1985). Squaring rate was measured in the period between first square and first open flower to avoid the reduction in squaring rate associated with increasing boll load (Ehlig and LeMert 1973).

The Simulations

To assess the sensitivity of simulated yield and time to 60% bolls open to changes in the developmental parameters, the model was run for a Siokra-type cultivar sown on October 10 at NARS with 150kg of nitrogen added and either grown dryland or fully irrigated. Simulations were run for each of 31 years of weather data collected at the NARS. The developmental parameters were then changed, one at a time, to reflect the actual range of variation found in the experiments, and the model re-run on the historical weather data.

Results and Discussion

Tables 1 to 4 present the average simulated yields and maturity times for the 31 years of historical weather data from NARS using the standard OZCOT parameters and using parameter values reflecting the range measured in the field experiments.

Table 1: Effect of the observed variation in the thermal time to first square on simulated lint yield (kg/ha) and time to 60% bolls open (days). OZCOT standard: 420 DD₁₂.

| | | Degree Days to First Square | | |
|-----------|--------------|-----------------------------|-------|-------|
| | | 420 | 475 | 530 |
| Irrigated | Av. yield | 1686 | 1688 | 1731 |
| | % change | 0 | 0.12 | 2.7 |
| | Av. maturity | 176.0 | 183.0 | 187.3 |
| | % change | 0 | 4.0 | 6.4 |
| Dryland | Av. yield | 684 | 673 | 629 |
| | % change | 0 | -1.6 | -8.0 |
| | Av. maturity | 160.5 | 166.6 | 167.1 |
| | % change | 0 | 3.8 | 4.1 |

Table 2: Effect of the observed variation in the square period on simulated lint yield (kg/ha) and time to 60% bolls open (days). OZCOT standard: 350 DD₁₂.

| | | Square Period | | |
|-----------|--------------|---------------|-------|-------|
| | | 280 | 350 | 420 |
| Irrigated | Av. yield | 1791 | 1686 | 1656 |
| | % change | 6.2 | 0 | -1.8 |
| | Av. maturity | 170.5 | 176.0 | 182.1 |
| | % change | -3.1 | 0 | 3.5 |
| Dryland | Av. yield | 819 | 684 | 603 |
| | % change | 19.7 | 0 | -11.8 |
| | Av. maturity | 157.6 | 160.5 | 165.5 |
| | % change | -1.8 | 0 | 3.1 |

Table 3: Effect of the observed variation in the boll period parameters on simulated lint yield (kg/ha) and time to 60% bolls open (days). OZCOT standards: $a=5.385$, $m=-0.0512$. The duration of the boll period in days was calculated using equation 1 and $T_{av}=25^{\circ}\text{C}$.

| | | Boll Period | | |
|-----------|--------------|--|------------------------------|--|
| | | $a = 5.128$ $m = -0.0433$ (57 d at 25°C) | $a = 5.385$ $m = -0.0512$ | $a = 5.196$ $m = -0.0433$ (61 d at 25°C) |
| Irrigated | Av. yield | 1714 | 1686 | 1721 |
| | % change | 1.7 | 0 | 2.1 |
| | Av. maturity | 171.1 | 176.0 | 176.6 |
| | % change | -2.8 | 0 | 0.34 |
| Dryland | Av. yield | 511 | 684 | 696 |
| | % change | -25.3 | 0 | 1.8 |
| | Av. maturity | 157.6 | 160.5 | 161.9 |
| | % change | -1.8 | 0 | 0.87 |

Table 4: Effect of the observed variation in the squaring constant on simulated lint yield (kg/ha) and time to 60% bolls open (days). OZCOT standard: Siokra=0.0228 DD₁₂⁻¹

| | | Squaring Constant | | |
|-----------|--------------|-------------------|--------|-------------------|
| | | 0.018 (slower) | 0.0228 | 0.024 (faster) |
| Irrigated | Av. yield | 1627 | 1686 | 1721 |
| | % change | -3.5 | 0 | 2.1 |
| | Av. maturity | 182.4 | 176.0 | 171.9 |
| | % change | 3.6 | 0 | -2.3 |
| Dryland | Av. yield | 717 | 684 | 689 |
| | % change | 4.8 | 0 | 0.73 |
| | Av. maturity | 163.8 | 160.5 | 161.5 |
| | % change | 2.1 | 0 | 0.62 |

Yield

Under irrigation the model was relatively insensitive to changes in the developmental characteristics in terms of simulated yield. The largest changes were caused by altering the square period: a range of 8% relative to the yield using the standard square period. The squaring constant gave a 5.5% change in simulated yield. In contrast, under dryland conditions, yield was very sensitive to the duration of the phases of fruit development. Square period again had the largest impact resulting in a 31% variation in yield. However, compared with the irrigated case, boll period also had a big effect resulting in a 27% variation in yield.

Maturity

The simulated time to 60% bolls open was most effected by square period under both irrigated and dryland conditions; a shorter square period giving earlier maturity. Under irrigated conditions, the range of square periods as measured in the field generated an 11.5 day difference in time to 60% bolls open and under dryland conditions an 8 day difference. The observed variation in boll period

parameters gave differences of 6 and 4 days in time to 60% bolls open for irrigated and dryland simulations respectively. This is consistent with the experimental findings of Gipson and Ray (1970) and Yfoulis and Fasoulas (1973).

Under irrigation, the squaring constant generated a 10.5 day difference in time to 60% bolls open with a higher squaring rate resulting in earlier maturity. It had little effect under dryland conditions. Higher squaring rates result in an earlier development of boll load. Boll load has been shown to be associated with reduced rates of flowering and decreased boll retention (Ehlig and LeMert 1973). Thus the simulated earlier maturity with higher squaring rate is consistent with expectation.

Conclusions

The results of the simulation study indicate that the model is responsive to varietal differences in characters known to influence fruiting dynamics in cotton; both in terms of yield and maturity time. Simulated changes in time to 60% bolls open were consistent with experimental evidence. It is therefore necessary to allow for these differences as inputs to the model. It is worth noting that while this paper presents the effects of varying one parameter at a time, varieties may differ in a number. This is particularly the case when comparing early and late varieties as traits associated with earliness often vary together (G.A. Constable, pers. comm.). The traits considered in this study will be assessed for a number of new and potential cultivars to maintain the relevance of the models to current production systems.

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