Impact of 'Cold Shock' on Early Development of Cotton

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Temperature plays many important roles in the growth and development of cotton. Low temperatures after sowing increase the time to emergence and reduce seedling vigour often leading to poor establishment, poor early growth and increased risk of seedling diseases. The timing of crop maturity, yield and fibre quality may also be affected. Research is being conducted to improve our understanding of the impacts of temperature extremes on cotton performance. In Australian cotton production systems events where the minimum daily temperature falls below 11°C are referred to as 'cold shocks'. The number of cold shocks is used by growers and advisors in assessing retardation of crops in their areas. However, this effect has not been tested explicitly. The aim of this work was to empirically assess impacts of cold shock on pre flower development of cotton plants. Cotton seedlings were grown in controlled temperature glasshouses. Plants were transferred to cold chambers ranging from 5 to 22°C during the night period for durations from 3 to 10 d. Negative impacts were not seen until plants had been exposed to at least 10 nights at 10°C, or for at least 5 nights at 5°C. When differences were generated it did not delay development to first square any more than 4 d, nor was the effect consistent. These differences translated into delays to first flower. However the delays are explained by the reduction in day degrees during the chilling period suggesting that there is no physiological damage to the plants. Improving understanding of the impacts of temperature extremes on cotton growth and development will help in developing more functional decision support tools and field management strategies.

Introduction

Low temperatures after sowing increase the time to emergence and reduce cotton seedling vigour often leading to poor establishment, poor early growth and increased risk of seedling diseases. Much of our current understanding of the impacts of temperature on cotton crop growth and development in Australia is based on experimental work undertaken in the early 1970's by Constable (1976) with cultivars quite different to those used commercially today. It was from these experiments that the current day degree function used in estimating crop development for cotton in Australia, was derived using a base temperature of 12°C (Constable and Shaw 1988).

To improve the accuracy of prediction using this function, it was postulated that early in crop growth there may be instances where chilling injury (cold shock) could delay crop development. A definition of a cold shock was then derived by selecting a minimum temperature that minimised the variation in the prediction of time to flowering. A cold shock was thus defined as where minimum daily temperatures are < 11°C and each event extends the duration to flowering by 5.2 day degrees (Hearn and Constable 1984). In some cotton producing regions in Australia early in cotton growth the number of cold shocks can be on average as frequent as 40 (period 15th Sep. to 30 Nov.) (Table 1). The distribution of cold shocks is often associated with cold front weather patterns moving

through eastern Australia during this period. This can sometimes happen once, or result in a sequence of cold nights together or spaced over longer periods.

Table 1. Average frequency of cold shocks (minimum temp < 11°) in major Australian cotton producing regions during early growth of cotton (15 Sep. to 30 Nov.)

Region	No. of Cold Shocks
Hillston NSW	40
Warren NSW	37
Gunnedah NSW	33
Bourke NSW	26
Narrabri NSW	30
Moree NSW	25
Goondiwindi Qld	37
St George Qld	16
Dalby Qld	22
Emerald Qld	4

Chilling studies on cotton growth and development beyond post-emergent seedlings are limited (Bange and Milroy, 2004). No studies have endeavoured to explicitly explore the impacts of short-term extreme low temperatures (cold shocks) imposed only at night on cotton growth and development beyond early post-emergent seedlings to flowering.

Our lack of understanding of the impacts of extreme temperatures on crop growth and development impedes our capacity to explore management opportunities to improve crop yield and profitability under such temperature extremes both from a genetic and agronomic perspective. These factors take on greater importance with the expansion of the Australian cotton industry into new regions which have increased the range and duration of hot and cold temperature. This paper presents research designed to quantify the effects of short term exposure of cold shock on crop growth and development. Six glasshouse experiments that exposed cotton to temperatures < 11°C were conducted to ascertain: 1. the existence of cold shock; 2. the temperature below which early development of post-emergent cotton seedlings will be delayed; and 3. which development processes are affected.

Materials and Methods

In each experiment cotton plants (cultivar Sicala V-2*i*) were grown in pots in controlled temperature glasshouses under natural light. Cold treatments involved exposing the plants to different low night temperatures for a number of consecutive nights. Experiments were conducted in the Canberra Phytotron and a glasshouse located at the Australian Cotton Research Institute Narrabri. The treatments in these experiments were imposed at different stages of crop development (prior to first flower) and for different durations. Experiments and treatments are summarised in Table 2. Across

the experiments the treatments covered night temperatures that ranged from 22°C to 5°C, periods of exposure that ranged from 3 to 10 nights, while the times of exposure varied from the four leaf stage to the time of first square. After the completion of the sequence of cold nights in all experiments all the plants were returned to the original temperature regimes and grown until either first square or first flower. Depending on the experiment measurements recorded for each plant included the date of appearance of the first square and the time of appearance of first flower.

Table 2. Description of experiments and treatments used to explore impact of short duration of cold night temperature (cold shock) on cotton growth and development. (DAS - days after sowing). Experiments 1 to 3 conducted in the Canberra Phytotron. Experiments 4 to 6 conducted in a glasshouse at the Australian Cotton Research Institute, Narrabri.

Experiment/Treatments (Month sown)	Pre/Post Treatment Temp. Day /Night °C	Timing of Cold Shock		Duration of Cold Shock	Cold Shock Temp. Day /Night °C
		Stage	DAS	No. Nights	
Exp. 1 Control (Oct. 2000)	30/22	no cold shock		-	30/22
T1	30/22	4 leaf stage	28	4	30/16
T2	30/22	4 leaf stage	28	4	30/14
T3	30/22	4 leaf stage	28	4	30/12
T4	30/22	4 leaf stage	28	4	30/10
T5	30/22	4 leaf stage	28	4	30/8
Exp. 2a Control (Oct. 2001)	30/22	no cold shock		-	30/22
T1	30/22	4 leaf stage	28	4	30/10
T2	30/22	4 leaf stage	28	4	30/6
Exp. 2b Control	23/15	no cold shock		4	23/15
T1	23/15	4 leaf stage	43	4	23/10
T2	23/15	4 leaf stage	43	4	23/6
Exp. 3a Control (Jan. 2002)	30/22	no cold shock		-	30/22
T1	30/22	4 leaf stage	20	10	30/10
Exp. 3b Control	23/15	no cold shock		-	23/15
T1	23/15	4 leaf stage	67	10	30/10
Exp. 4 Control (Sep. 2001)	34/20	no cold shock		-	34/20
4L	34/20	4 leaf stage	30	3	34/5
4L+1	34/20	4 leaf stage + 1 week	37	3	34/5
4L+2	34/20	4 leaf stage + 2 weeks	44	3	34/5
4L+3	34/20	4 leaf stage + 3 weeks	51	3	34/5
Exp. 5 4L Control (Nov. 2001)	38/21	4 leaf stage	27	-	38/19
4L	38/21	4 leaf stage	27	5	38/5
4L+1 Control	38/21	4 leaf stage + 1week	34	-	38/19
4L+1	38/21	4 leaf stage + 1week	34	5	38/5
4L+2 Control	38/21	4 leaf stage +	41	-	38/19

		2weeks			
4L+2	38/21	4 leaf stage + 2weeks	41	5	38/5
Exp. 6 4L5 Control (Feb. 2002)	39/21	4 leaf stage	22	-	39/19
4L5	39/21	4 leaf stage	22	5	39/5
4L10 Control	39/21	4 leaf stage	22	-	39/19
4L10	39/21	4 leaf stage	22	10	39/5
S5 Control	39/21	first square	42	-	39/19
S5	39/21	first square	42	5	39/5
S10 Control	39/21	first square	42	-	39/19
S10	39/21	first square	42	10	39/5

Results

To generate effects on cotton growth and development, plants needed to be exposed to night temperatures of 5°C for at least five nights consecutively or to 10°C for at least 10 nights. Cold night treatments in Experiments 1, 2, and 4 had no effect on either time to first square or first flower. In Experiment 3 a longer duration of exposure to less severe cold night temperature (10 nights at 10°C) increased the time to first square by 2.8 d for plants that had been growing in the 30/22°C day/night temperature regime. This effect translated into a later time for first flower. No effects on time to first square occurred in plants that had been growing in the 23/15°C day/night temperature regime. In experiment 5 the application of a longer cold shock treatment (five nights at 5°C) at the four leaf stage significantly delayed first square by approximately 3 d and flowering by 4 d. In experiment 6 when plants at the four leaf stage were exposed to cold shock for 10 nights at 5°C first square was delayed 4 d. In the same treatment flowering was delayed by 5 d. Cold shock applied for 5 nights just after squaring also significantly delayed flowering

To test whether the delays in crop development were simply due to less day degrees rather than 'cold shock', we calculated the day degrees accumulated to the appearance of first square using the day degree method of Constable and Shaw (1988). When the treatments were compared to their relevant controls, the resulting day degrees were no different in Experiment 3, approximately 30 day degrees more in Exp. 5 and Exp. 6. This analysis showed that on at least two occasions there was some delay associated with the cold shock that was not accounted for using day degrees alone. However, although there were differences in these two treatments, when the day degrees for all the cold shock treatments were compared against their controls there was no significant increase in either day degrees to first square or to first flower (Fig. 1). That is the regression line did not differ significantly from the 1:1 line.

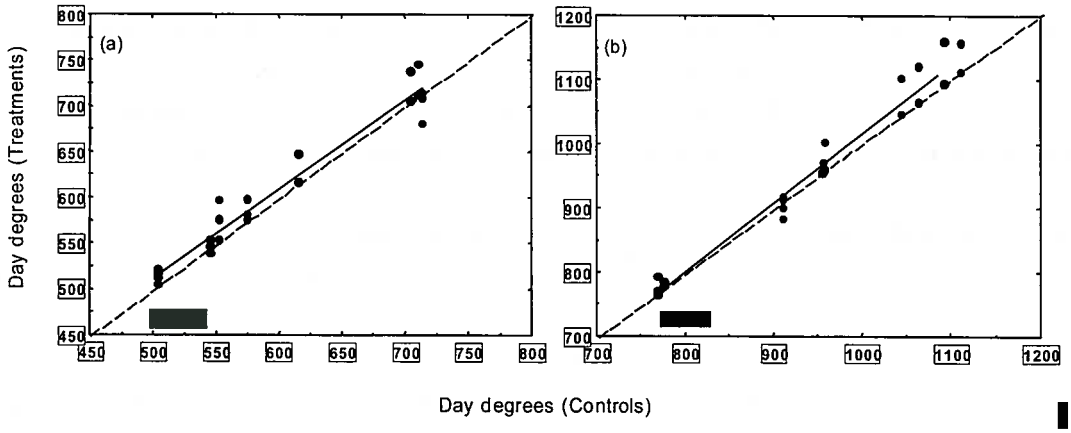

Figure 1. Day degree accumulation calculated for all cold shock treatments across all experiments plotted against the control for the related treatment for (a) time to first square and (b) time to first flower. Also shown are the 1:1 lines.

Discussion

Imposing a range of cold night treatments to explore cold shock in cotton and implications for crop development we were able to establish:

1. There was little evidence that short duration exposure of cotton to cold night temperatures had any significant impact on early crop development.
2. On one occasion there was some evidence that there was some effect of antecedent conditions modifying the impact of cold night temperatures.

Based on the previous understanding of chilling in cotton we expected that all the cold night temperatures treatments below 11°C imposed in this study would have caused delays to plant development. Despite the imposition of extreme night temperatures for considerable durations early in crop growth there was no great or consistent effect on any aspect of plant development and growth up to flowering. In order to generate some effects, we had to expose the plants to night temperatures of 5°C, or lengthen exposure to 10 nights at 10°C. Taking the results as a whole the cumulative day degree (without any adjustments for cold shocks) to first square or first flower was not significantly increased (Fig. 1). Hearn and Constable (1984) defined cold shock as when minimum daily temperatures were < 11°C and this was believed to extend the duration to flowering by 5.2 day degrees for each cold shock event. No evidence gathered in our studies indicated that 11°C was a suitable temperature threshold for post-emergent cotton to account for an impact of chilling/cold shock on crop development.

An examination of the original data used by Hearn and Constable (1984) shows little effect and high variability when fewer than ten cold nights were experienced. However as can be seen from the average number of cold shock days at most locations in Table 1, cotton plants experience a larger number of cool nights. It appears that accumulation of more than 10 cool nights is required to delay development. Our controlled environment experiments may have been expected to reduce

background variability and hence increase statistical sensitivity in this range. However, this was not the case. There is clearly a need for controlled environment studies to explore the impact of low night temperatures over a longer duration, free of possible confounding effects of increased seedling disease or herbicide damage that are correlated with poor seedling growth in the field.

While there is some indication of the existence of a chilling effect caused by low night temperatures, the results show little indication of a consistent or general cold shock (unless treatment was severe) impacting crop growth and development when imposed between the four leaf stage and flowering. This is consistent with the view of Cothren (1999) who suggests that cold tolerance has been exhibited in certain wild species in the *Gossypium* genus and suggests that this trait may be introgressed into cultivated species. The persistence of the use of a cold shock to adjust estimates of crop development may be perpetuated by inadequacies of the base temperature of 12°C used in the calculation of day degree used in the Australian cotton industry (Constable and Shaw 1988). In other studies we have shown that the base temperature for Australian cultivars is closer to 15 than 12°C (Bange and Milroy 2001). Fifteen is a value similar to that quoted generally in cotton literature (Mauney 1986). This may account for many instances where predictions in crop development are earlier than observed, and the observed delay attributed to cold shocks.

Conclusion

Research is continuing in an effort to determine those temperatures and situations where chilling/cold shock may occur as well as investigating the impacts of cold night temperatures on other stages of crop development. The importance of acclimation and antecedent conditions are two key areas where further work is required. The pattern of recovery in photosynthetic rate and consequences on final yield also needs to be assessed. In gaining a better understanding of the impacts of temperature extremes we will be able to use this information to develop more functional decision support tools and field management strategies which will enable both research and management to be done more accurately in scenarios where extremes of temperature are likely.

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