Cold shock in early growth of cotton

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Abstract

A previous analysis of the rate of cotton development has shown that minimum temperatures below 11?C delay the development of cotton seedlings compared with the expected rate based on the accumulated day degree sum. Events where the minimum daily temperature fall below this value are referred to as 'cold shocks'. The number of cold shocks occurring in the early parts of the cotton growing season are used by growers and advisors in assessing retardation of crops in their areas. However, this 'cold shock' effect has not been tested explicitly.

The aim of this work was to empirically assess impacts of cold shock on crop growth and development. Cotton seedlings were grown under natural light conditions in controlled temperature glasshouses. To impose cold shock plants were transferred to cold chambers ranging from 3 to 22? C during the night period for durations from 3 to 10 d. In order to generate some effect, plants grown in 30/22? C day/ night temperatures had to be exposed to 10? C for 10 d to delay time to first square and first flower, but this effect did not translate into differences in leaf area or total dry matter measured just after flowering. Plants exposed for a similar duration at the same temperature that had been grown in a 23/15? C day/ night regime showed no significant differences in any parameter measured, possibly indicating some degree of cold acclimation. In one experiment a significant reduction in leaf photosynthesis was measured the day after the initial cold shock at 3 ? C, but this did not impact on crop time to flowering or total dry matter measured at flowering.

This work is intended to improve understanding of the impacts of temperature extremes on cotton growth and development to help 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.

Key Words

Temperature, growth, development, Gossypium hirsutum

Introduction

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 (1). 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 (2) with cultivars quite different than those used commercially today. It was from these experiments that the current day degree function used in estimating crop development was derived using a base temperature of 12 ?C. To improve the accuracy of prediction using this function, it was postulated that early in crop growth there may be instances where a chilling injury (cold shock) could occur which could delay crop development. A value defining a cold shock was then derived from a simple iterative procedure that minimised the coefficient of variation in the prediction of crop development. A cold shock was defined as where minimum daily temperatures are < 11 ?C and this extends the duration to flowering by 5.2 day degrees.

Studies of chilling (temperatures above 0 ?C) on crop growth in other crops is comprehensive (4), but for cotton growth and development they are limited (5). Those studies that have explored chilling in cotton have focused their attention on the period from seed germination to post-emergent seedlings (5). Temperatures less than 10 ?C during this period can have significant effect on reducing cotton growth and development (6). One exception was a study comparing the growth of cotton with two weed species, where a cold shock was imposed for 3 d (7). Reductions in crop growth were measured but this cold shock was imposed continually through day and night. No studies have however, endeavoured to explicitly explore the impacts of short-term extreme low temperatures (cold shocks) imposed at night on cotton growth and development beyond 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 (both from a genetic and agronomic perspective) under such temperature extremes. These factors take on greater importance with the expansion of the cotton industry into new regions which has increased the range and duration of hot and cold temperature to which the crop may be exposed. This paper presents results from ongoing temperature research in cotton attempting to quantify the effects of cold shock on crop growth and development. Glasshouse experiments have been conducted to determine the conditions in which cold shock may occur and to establish growth and development processes affected by cold shock.

Methods

The impact of cold shock on plant growth and development was explored in a series of experiments conducted under natural light in controlled temperature glasshouses. Seedlings of cultivar Sicala V-2*i* were established in 9 litre pots, one plant per pot. Cold treatments involved exposing the plants to low night temperatures for a number of consecutive nights. During the cold shock treatments, pots were insulated from the chamber floor using Styrofoam sheets. Experiment 1 (Exp. 1) explored the impact of different night temperatures on plant development. Experiment 2 (Exp. 2) reduced the night temperature compared with Exp. 1 and varied the stage of the plant at which the exposure was implemented. Experiment 3 (Exp. 3) increased the duration of exposure to cold night temperatures on plants grown previously in two distinct temperature environments (Exp. 3a & b). Experiments and treatments are summarised in Table 1.

Table 1. Description of experiments and treatments used to explore cold shock. (DAS – days after sowing).

Experiment/ Treatments	Pre/Post Treatment Temp. Day /Night ?C	Timing of Cold Shock	Duration of Cold Shock (nights)	Cold Shock Temp. Day /Night ?C
Exp. 1 Control	30/22	no cold shock	-	30/22
T1	30/22	4 leaf stage (DAS – 28)	4	30/16
T2	30/22	4 leaf stage	4	30/14
T3	30/22	4 leaf stage	4	30/12
T4	30/22	4 leaf stage	4	30/10

T5	30/22	4 leaf stage	4	30/8
Exp. 2 Control	34/20	no cold shock	-	34/20
T1	34/20	4 leaf stage + 1week (DAS – 30)	3	34/3
T2	34/20	4 leaf stage + 2weeks (DAS – 37)	3	34/3
Exp. 3a Control	30/22	no cold shock (DAS – 20)	-	30/22
T1	30/22	4 leaf stage	10	30/10
Exp. 3b Control	23/15	no cold shock (DAS – 67)	-	23/15
T1	23/15	4 leaf stage	10	30/10

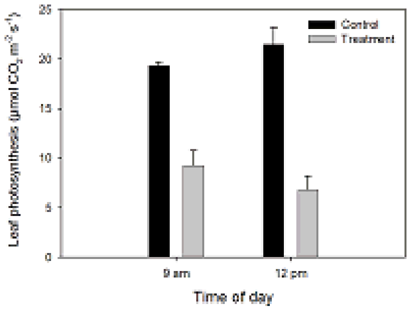
Plants were monitored frequently to determine the date of appearance of first square and first flower.

When all plants in the experiment had reached first flower they were cut off at ground level and the total number of fruiting sites, total dry matter, harvest index, and leaf area per plant recorded. In Exp. 1 only the time of first square was measured. In Exp. 2, on the day after the first night of cold treatment on treatment 1 (4 leaf + 1 week), leaf photosynthesis measurements were made on the fourth unfurled leaf from the apex of each treatment plant and the control plants. Measurements were taken using an IRGA with a red/blue LED light at 0900 h and then again at 1200 h. The light intensity was set at approximately ambient conditions for the glasshouse.

Results

In Exp 1. there were no significant differences in the time to first square in exposing young cotton plants to night temperatures ranging from 22 to 8 ?C for four nights (Figure 1a). In Exp. 2 where night temperatures were lowered to 3 ?C for three nights there was again no significant effect on time of first square (Figure 1b). Increasing the duration of cold temperature exposure to 10 d at 10 ?C did however, increase the time to first square by 2.8 d for plants that had been growing in the 30/22 ?C day/night temperature regime (Figure 1c). This effect translated into a later time for first flower (Table 2). No effects on time to first square were measured in plants that had been growing in the 23/15 ?C day/night temperature regime (Figure 1c). Total dry matter, harvest index, fruiting sites and leaf area index at flowering were not significantly different in both Exps. 2 and 3 (Table 2).

Figure 1. Days to first square in (a) Exp. 1, (b) Exp. 2 and (c) Exp. 3. Error bars are the standard error of the mean.



Leaf photosynthesis in Exp. 2 was significantly reduced at both 9000 and 1200 h following a single night of exposure to 3 ?C (Figure 2).

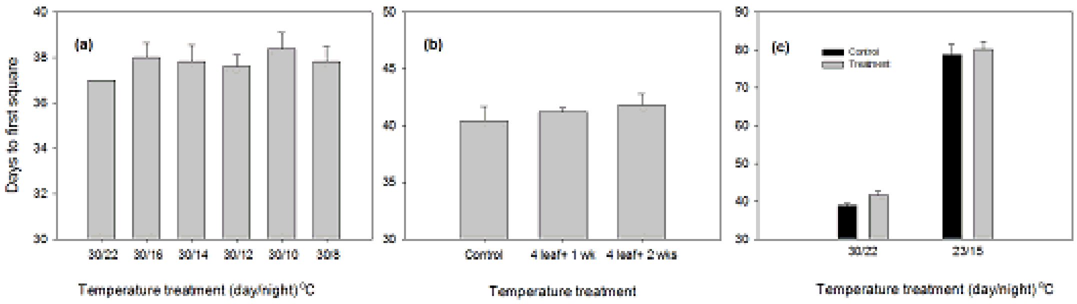


Figure 2. Leaf photosynthesis measured at two times after the first day of cold shock in treatment 1 of Exp. 2. Error bars are the standard error of the mean.

Table 2. Growth and development parameters measured in Experiments 2 and 3 at flowering. (DAS – days after sowing; * (*P* < 0.05); lsd – least significant difference).

Experiment/ Treatment	DAS first flower	Total fruiting sites	Leaf Area (cm^2)	Final dry weight (g)	Final Harvest Index
Exp. 2 Control	61.6	16	1363.0	33.6	0.21
4 leaf + 1 week	62.8	15	1424.5	29.9	0.19
4 leaf + 2 weeks	61.8	17	1552.7	34.3	0.18
lsd	2.9	3	228.5	3.6	0.07
Exp. 3a Control	55.0*	-	2524.1	30.1	-

Treatment	58.3	-	2662.8	32.3	-
lsd	2.1	-	303.7	3.8	-
Exp. 3b Control	111.3	-	2582.8	53.9	-
Treatment	113.6	-	2853.3	60.5	-
lsd	7.6	-	310.5	7.5	-

Discussion

Despite the imposition of relatively extreme night temperatures for considerable durations early in crop growth there was little effect on any aspect of crop development and growth to flowering. In order to generate some effect, plants grown in 30/22 ? C day/night temperatures (Exp. 3a) had to be exposed to 10? C for 10 d to delay time to first square and first flower, but this effect did not translate into differences in leaf area or total dry matter measured at flowering. Plants exposed for a simular duration at the same temperature that had been grown in a 23/15 ? C day/ night regime showed no significant differences in any parameter measured, possibly indicating some degree of cold acclimation.

To test whether the delay in squaring in Exp. 3a was due to less thermal time rather than 'cold shock' per se, we calculated the thermal time accumulated to the appearance of first square using the thermal time method of Constable and Shaw (1). The resulting day degrees were 546 for the control and 538 for the treatment. This analysis showed that there was no increase in thermal time indicating that the delay may be accounted for using day degrees. In other experiments we are exploring the adequacy of the thermal time response (8). These studies are showing that the base temperature that is used in the industry day degree function is closer to 15 than 12 ?C. This may account for many instances where predictions in crop development are earlier than observed, and the observed delay attributed to cold shock.

Despite reductions in photosynthesis measured in Exp. 2 there were no effects on leaf area and dry matter accumulation at flowering. The effects of cold daytime temperatures on photosynthesis have significant impacts on crop growth (9), but there is little evidence on the effects of night temperatures alone. Reasons why the leaf photosynthesis from cold night temperatures had no impact on crop growth require further exploration.

Conclusion

These results show little indication of cold shock impacting crop growth and development following the post-emergent growth phase to flowering. Research is continuing in an effort to determine those temperatures and situations where cold shock may in fact occur as well as investigating the impacts of cold night temperatures on other stages of crop development. 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.

Acknowledgments

Thanks to Chris Stonehouse, Marian Zajac, Jane Caton, Tanya Smith and Graeme Rapp for technical assistance with the controlled environment experiments. The Cotton Research and Development Corporation provided financial support for this work.

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