Effect of early moisture deficit on growth, development and yield in high retention Bt cotton

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Abstract

The release of Bt cotton (Bollgard II?) varieties can provide increased insect protection compared with non-Bt varieties with similar gene backgrounds, leading to increased early boll load due to higher fruit retention. The earlier and higher sink demand on a smaller plant may lead to early cut-out and lower yields of Bollgard II cotton compared with the equivalent non-Bollgard II conventionally managed varieties. While the effect of water stress in cotton have been studied by numerous researchers, it is unclear whether manipulation of water management prior to flowering can increase the vegetative biomass for enhanced provision of assimilates for the development and maturation of the early bolls and maximizing the yield potential of Bollgard II varieties. Traditionally early irrigation management (pre squaring) is less in non-Bollgard II crops as early fruit loss is often encountered and there is less demands on the crop thus limiting stress.

Two experiments with the Bollgard II variety Sicot 71BR were conducted at the University of Queensland, Gatton Campus, southeast Queensland to study biomass accumulation and partitioning during vegetative stage until flowering and its effect on reproductive growth under different levels of available water: including well irrigated (WI) over the whole crop season, water stress until squaring (WSS) followed by full irrigation and water stress until flowering (WSF) followed by full irrigation until the end of season. Two methods were used to create the water stress treatments: rainout shelters Experiment 1 and plastic cover of inter-row space in Experiment 2. Plastic was removed when the treatments finished allowing full irrigation to commence. Soil water was monitored frequently to maintain the irrigation treatments.

Leaf area index, vegetative and reproductive biomass, retention of bolls were found to increase in well watered treatments. WSF and WSS treatments also reduced the time to cut-out and maturity and produced less seed cotton. The results indicate the earlier irrigation management in Bollgard II cotton can increase early vegetative growth to support greater fruit retention and growth of bolls leading to improved yields.

Key words

Bt cotton, water stress, early biomass, high retention

Introduction

Cotton is attacked by a range of insects, the most significant of which is the larvae of *Helicoverpa* spp. These larvae feed on the developing fruit (flower buds or squares and bolls), causing them to shed. This reduces fruit retention, especially early season and delays cutout (the point at which the boll load (sink) is high enough that their demand for assimilate fruit equals supply from the vegetative biomass of plants (source) and the plant essentially ceases to set more fruiting sites). Bollgard II cotton varieties containing two genes from *Bacillus thuringiensis* var *kurstaki* (Bt) that express proteins toxic to *Helicoverpa* spp., can have increased insect protection compared with conventionally non-Bollgard varieties with similar genetic backgrounds managed conventionally with insecticides, leading to increased early retention and hence boll load. Bollgard II varieties in many instances have higher early fruit retention, faster accumulation of boll weight and lower leaf area than their conventional equivalents (Yeates 2006).

The higher sink demand on a smaller plant may cause earlier cut-out and maturity and reduce yields in Bollgard II crops in long season growing regions. Earlier maturity in these regions is known to reduce yield (Stiller et al. 2004). However, it may be possible manipulate water supply before flowering to increase the vegetative biomass for enhanced provision of assimilates for the development and maturation of the early bolls and increase the yield potential of Bt crops. Traditionally, crops are irrigated to ensure germination then not irrigated again until early fruit set has begun (early December) as the demands on non-Bollgard II crops are less earlier as there is often loss of fruit due to insect damage. Earlier provision of water may encourage more vigourous growth so we quantified the biomass accumulation and partitioning of Bollgard II crops and its effect on reproductive growth and yield under different levels of early season water supply.

Methods

The field experiments were conducted at the University of Queensland, Gatton Campus (91m altitude, 27?33'S, 152?20'E), southeast Queensland, Australia in the 2006-2007 season. The experiments were planted 16 (Experiment 1) and 21 (Experiment 2) November 2006 using Bollgard II[?] (Monsanto) variety Sicot 71BR (CSIRO, Australia; Bt cotton producing 2 insecticidal cry proteins) in a randomized complete block design with four replications. Row spacing was 1 m and plant density was 140 000 plants ha^{-1} (12 to 15 plants m^{-1}). The experiments were provided with different levels of soil moisture, including well irrigated (WI) over the whole crop season, water stress until squaring or 46-50 days after sowing (DAS) (WSS) followed by full irrigation and water stress until flowering or 69-72 DAS (WSF) followed by full irrigation until the end of season. The irrigation was conducted using overhead sprinklers.

Two methods were used to create the water stress treatments: rainout shelters in Experiment 1 and plastic covering of inter-row space in Experiment 2. Plastic was removed when the treatments were finished to allow full irrigation to commence. Soil water was monitored (weekly?) to maintain the levels of water in each treatment using a neutron probe moisture meter per plot. Harvests for biomass (dry matter), partitioning and seed cotton yield, as well as plant mapping for total % fruit retention (fruit present/total fruiting sites*100), were done at various developmental stages (maybe name them) throughout the season. The average maximum and minimum air temperature were 31°C and 17°C respectively and the average solar radiation was 22.7 MJ m^{-2} d^{-1}.

Results and Discussion

The pattern of growth and development was different between treatments. WSS and WSF resulted in earlier maturity (60% open bolls) compared with WI in both experiments. For WSS maturity was 141 (experiment 1) and 147 DAS (experiment2) and for WSF was 136 (experiment 1) and 143 DAS (experiment 2), while for WI was 152 (experiment 1) and 151 DAS (experiment 2). The amount of water (rainfall plus irrigation) added in each treatment was similar in both experiments. In WI treatments the soil water was near to the total soil water for most of the season (610 and 620 mm was applied in experiments 1 and 2 respectively). In contrast, the WSS and WSF treatments with soil moisture deficits until squaring and flowering respectively; started the irrigated period with enough water supplied to fill only the upper part of the soil profile (over the whole of the season? 469 and 409 mm was applied in experiment 1 and 2 respectively for WSS; 370 and 320 mm was applied in experiment 1 and 2 respectively for WSF).

Differences in total biomass were found from first flower in experiment 1, while in experiment 2 was just after First Square. There were no significant differences (lsd. 0.05) in total biomass before those stages. WI produced more early vegetative and reproductive compared with WSS and WSF (data not presented). The response of leaf area index to soil water deficits was consistent across experiments. Treatments with early soil moisture deficits (WSS and WSF) produced a lower LAI compared with WI treatments. Significant differences (lsd. 0.05) in LAI between treatments were found at first flower, peak flower and maturity (defined as 60% bolls open). In Experiment 1, the maximum LAI in the period around 90 to 100 DAS (peak flowering?) (dependant on the treatment) was 3.65, 1.82 and 1.12 while in Experiment 2 it was 4.40, 2.88 and 2.39 for WI, WSS and WSF respectively.

In both experiments, Bollgard II under WI showed significant? increases in percentage of fruit retained compared with WSS and WSF. In Experiment 1, fruit retention at all sites at first flower was 86.6, 79 and 77% in WI, WSS and WSF respectively and a similar trend was found with final seed cotton yield (weight of seed and lint combined, Figure 1).

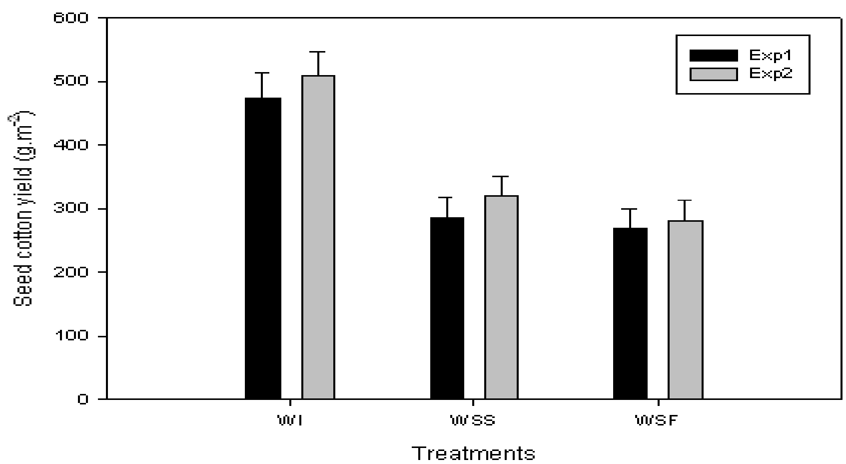

Figure 1: Seed cotton yield in WI, WSS and WSF in Experiment 1 and Experiment 2 at Gatton 2006-07. (Bars indicate standard errors of the mean).

The differences in dry matter production and partitioning and the time to maturity show that inputs of water early on the season significantly influenced the pattern of growth and development of Bollgard II. Treatments with higher early water deficits, had reduced LAI, total number of fruiting sites, reduced number of bolls and increased shedding of fruiting sites and bolls resulting in reduced % retention, all resulting in less yield compared with WI treatments. Higher biomass produced in WI may have also led to greater partitioning to reproductive organs in contrast with early soil moisture deficit treatments (WSS and WSF), also resulting in higher fruit retention. These effects were consistent with other studies on the effects of water stress on cotton growth and development (Hearn??,Pettigrew (2004ab)).

Conclusion

These studies highlight the importance of early irrigation management needed for high fruit retention Bollgard II cotton. Results presented here suggest that there is stress imposed on Bollgard II cotton when traditional irrigation practices are employed leading to less yield. Future research will … and is part of an overall research effort to manipulate cotton growth to raise yields and improve agronomic water use efficiency.

References

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