How important is early season damage?

Lewis Wilson[1] and Victor Sadras[2]
[1]CSIRO Cotton Research Unit, [2] University of Mar del Plata, Argentina.

Summary
Experiments were done using simulated damage to investigate responses of early season cotton to defoliation, tipping out and fruit removal in a range of combinations and intensities. Pre-squaring cotton was very tolerant of relatively high levels of tip damage, even when combined with other forms of damage such as defoliation of fruit removal. Heavy early fruit loss did not affect yield but caused a delay in maturity of about seven days. The yield of pre-squaring cotton was unaffected by defoliation, even when 100% of true leaves were removed on three occasions. Pre-squaring cotton was tolerant of defoliation levels of up to 80% loss of true leaf area without affecting maturity. The capacity of cotton to recover from early damage has important implications for developing IPM systems.

Introduction
High yields and early crop maturity are the goals that most cotton producers aspire to. Achieving these goals is a difficult task - balancing the agronomic needs of the crop to ensure optimal yield potential, protecting it from pests that will eat away at that potential and all the while keeping in mind the risks and costs of producing the crop. Early in the season the growth of cotton is often slow and the effects of pest damage highly visible. This has lead some to suggest that to produce a bumper high yielding, early crop requires a high degree of protection of the crop from insect damage early in the season - especially from insect pests (e.g. Parvin, 1989)]. This philosophy is not supported by a wealth of experiments, both in Australia and overseas, which suggest cotton is able to tolerate quite severe early season damage with little, if any, effect on either yield or earliness (Brook *et al.*, 1992; Sadras and Wilson, 1998; Terry, 1992).

Why is the issue of early pest management so important, when the cost of controlling early season pests is inexpensive in comparison to the cost of controlling pests such as *Helicoverpa armigera* late season? As young cotton emerges from the soil and begins to grow, a range of insects move into the crop, including both potential pests and predators. Management decisions made at this time can have a lasting impact on crop management for the rest of the season. Decisions to control or not to control early season pests can affect yield or earliness, but can also affect other components of cotton production, particularly the survival of beneficial populations (Wilson *et al.*, 1998; Wilson *et al.*, 1996).

Beneficials form the basis of most IPM systems and in cotton they contribute significantly in management of secondary pests (mites and aphids) and *Helicoverpa* spp. thereby reducing the need to spray and reducing insecticide selection pressure on *H. armigera*. Growers and consultants therefore need reliable information about the response of cotton to different types and combinations of early season damage in order to judge when a crops needs protection in order to prevent yield loss or delay and when it doesn't. A balance must be sought between controlling what could be economically damaging pests and preserving

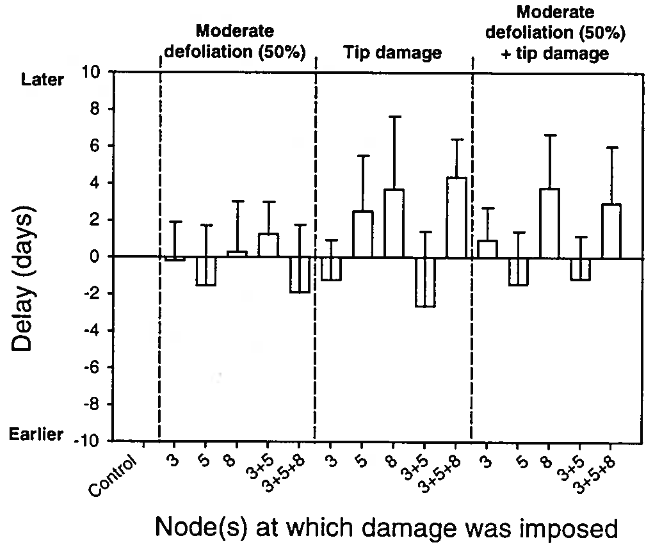

Figure 2. Maturity (delay) was not affected by defoliation, tip damage nor the combination of defoliation and tip damage in experiment 1.

Experiment 2

Yield was not significantly affected by early season defoliation, tipping out or fruit removal (Fig. 3), even in the treatments combining 100% leaf removal with tipping out and early fruit loss. In contrast maturity was significantly delayed by some treatments (Fig. 4). Moderate defoliation had no effect on maturity, but defoliation of 100% twice caused a delay in maturity of about 13 days. Fruit removal caused a delay in maturity of about seven days, which was additive - that is it caused a delay of about this magnitude regardless of whether other forms of damage were also present. This is clear with moderate defoliation which alone had no effect on maturity alone but which was delayed by about 7 days when fruit damage was added (Fig. 4). Addition of tipping out (100% of plants tipped out twice) had no effect on maturity, even when imposed on top of other 'heavy damage' treatments.

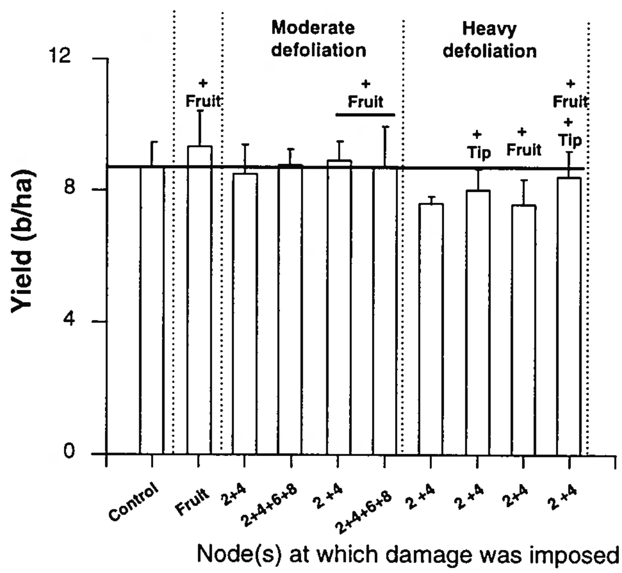

Figure 3. Yield was not significantly affected by defoliation, tip damage or fruit removal in experiment 2.

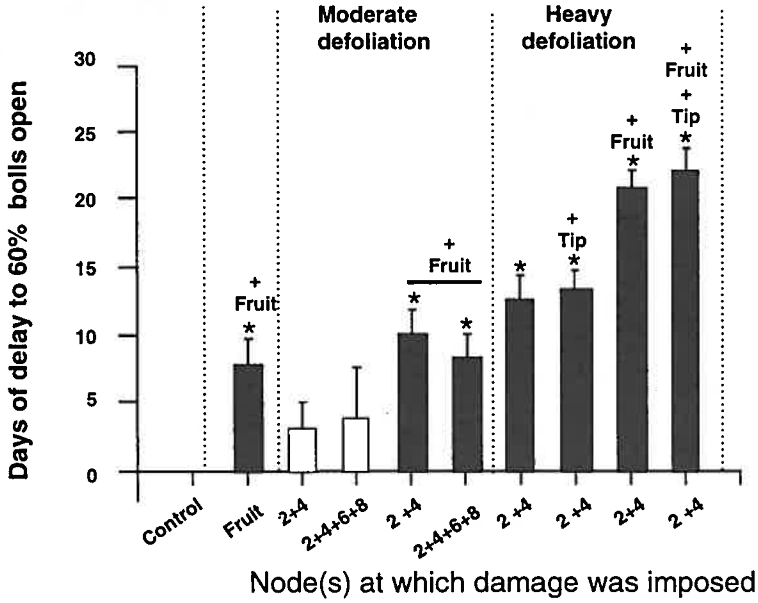

Figure 4. Maturity was delayed by severe early defoliation or fruit loss but not by moderate defoliation or tip damage in experiment 2. Asterisks and black bars indicate treatments significantly different from the control.

Experiment 3

Defoliation up to 100% twice or three times had no effect on yield (Fig. 5). Only the heaviest defoliation treaments affected maturity. Defoliation of 100% twice or three times caused significant delays of about 5 and 9 days respectively. In the treatments which were damaged twice damage levels of 80% or less had no effect on maturity. In the treatment which were damaged three times there was a trend toward increasing damage causing increasing delay, but damage up to 80% still did not cause a significant delay in maturity.

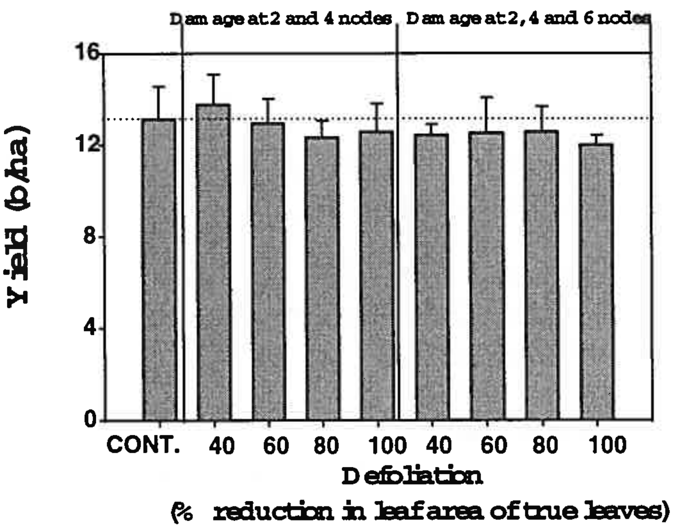

Figure 5. Defoliation did not affect yield in experiment 3. Percentages refer to the percentage reduction in the leaf area of true leaves, cotyledons were undamaged.

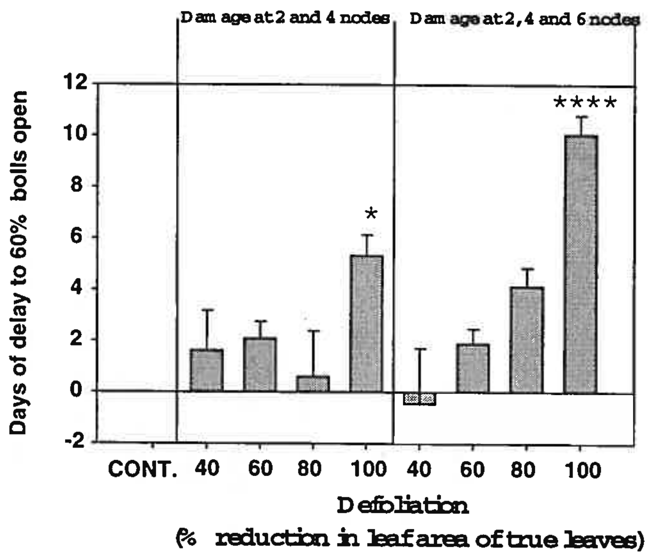

Figure 6. Only severe defoliation caused significant delay in experiment 3. Asterisks indicate treatments significantly different from the control (* = $p < 0.05$, **** = $p < 0.001$). Percentages refer to the percentage reduction in the leaf area of true leaves, cotyledons were undamaged.

Discussion

Outcomes of experiments

Several key conclusions can be drawn about the responses of cotton to damage from the results of these three experiments;

1. Pre-squaring cotton was very tolerant of relatively high levels of tip damage, i. e. 100% of plants tipped out up to three times did not affect yield or maturity. This held true even when tip damage was combined with other forms of damage such as defoliation of fruit removal,

2. Heavy early fruit loss (all fruit lost from first four fruiting branches) did not affect yield but did cause a delay in maturity of about seven days,

3. The yield of pre-squaring cotton was unaffected by defoliation, even when 100% of true leaves were removed on three occasions,

4. Pre-squaring cotton is tolerant of defoliation levels of up to 80% loss of true leaf area without affecting maturity. Defoliation of 100% of true leaf twice was required before there was a significant delay (5 days).

Implications for pest management

These experiments were all done in the lower Namoi Valley, which is a warm or 'full season' region. The results have significant implications for early season pest management in full season regions, but to some extent the principles will also apply in cooler 'short season' regions.

Early season tipping out had no significant effect on yield or maturity which is not surprising given the results of other similar studies (e. g. Brook *et al.*, 1992). In the field, thrips only cause tip damage if they are present in extremely high numbers, usually that means in excess of about 30 thrips per plant. Comparisons of the degree of early tip damage in conventional and Ingard cotton show that most tipping out is due to *Helicoverpa* rather than thrips, contrary to conventional wisdom. The tip damage treatments therefore simulate the effect of early season *Helicoverpa* damage, where an egg hatches and the neonate moves quickly to the growing tip which is the most nutritious and sheltered position on the plant. Often the neonate will damage the tip then die, either due to exposure to unsuitable environmental condition (wind, rain) or predation. When the crop is checked the terminal is recorded as tipped out, thrips are present but no larvae is found - possibly leading to the conclusion that thrips are the cause. In terms of IPM the results suggest that reasonably high levels of tipping out can be tolerated without the need to spray.

The degree of early season defoliation imposed in this experiment ranged from the equivalent of very light to very heavy thrips pressure. The results in these experiments confirm the conclusion, from field experiments with thrips, that such levels of damage are cosmetic, despite their dramatic appearance. In the field experiments by the authors, by NSW Agriculture and by Cotton Seed Distributors have shown that in warm or full season areas damage by thrips is likely to affect yield in about 1 year in ten. Plants suffering early defoliation may appear to be growing much worse than protected ones, but in fact the plant is able to recover fully from this degree of damage. These findings confirm those of Lane (1959) who found that defoliation levels in excess of 80% were generally required to reduce the yield of seedling and pre-squaring cotton.

Heavy early fruit damage can cause a delay in maturity. However the results show that fruit damage does not interact with early defoliation or tip damage, but has an additive effect. This has two key implications for IPM in cotton. Firstly, work by Dallas Gibb shows that yield is maintained provided early fruit retention levels of 60% are maintained. Our data shows that even in a worst case scenario when all early fruit is lost yield was unaffected, though maturity was delayed by a week. Secondly, early season fruit loss does not hinder the capacity of the plant to recover from earlier tip damage or defoliation.

Studies of this nature help us to understand the responses of cotton to specific types, duration and combinations of damage. Although, as we said before, simulated damage is not exactly the same as actual insect damage, the agreement between studies looking at simulated damage and those using actual insect damage is encouraging. For instance, trials with artificial leaf removal and actual leaf area reductions caused by thrips both showed that no yield reductions or delays occur up to 50% leaf loss. Future research will concentrate on this key pre-squaring period where plants are essentially in vegetative growth mode. Combinations of increasing leaf damage, tip damage and fruit damage (simulating later attack by Helicoverpa or mirids) will be investigated. We also intend to explore the interactions between damage and plant density and between damage and seedling vigour to determine how these may affect the crops responses to damage.

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