Physiological Responses of Cotton to Damage by the Two-Spotted Spider Mite

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Introduction

Spider mites are world-wide pests of a variety of crops. They are important pests of cotton as they can reduce plant vigor which leads to reduced yield (up to 90%), inferior fibre and inferior seed quality (Wilson, 1993); control of spider mites is expensive and they are able to develop resistance to miticides. The two spotted spider mite comprises 99% of cotton mite pests in Australia.

Spider mite ecology (Figure 1: **I**) and the effect of mites on the yield and fibre quality (Figure 1: **III**) of cotton in Australia has been established by Wilson (1992). However there is a lack of understanding of the physiological mechanisms (Figure 1: **II**) underlying the response of cotton to mite damage which results in yield loss. At present, Wilson's statistical model for predicting yield loss from mite damage is not suitable for use in crop simulation models.

Modelling requires an understanding of the physiological aspects affected by mites and more complex interactions (ie. the effect of mite stress combined with water stress or nutrient stress) need to be allowed for. A knowledge of the plant response to mite feeding is necessary to understand the relationship of mite populations to actual yield and to develop better pest management programs.

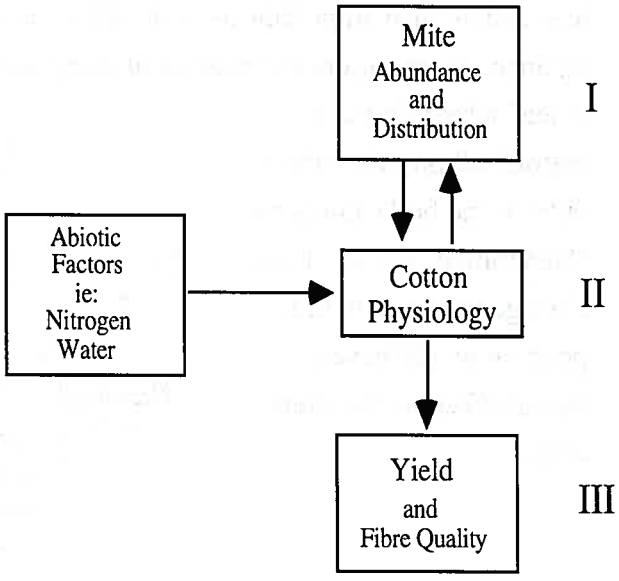

Figure 1: The missing link (II) between mite populations (I) and cotton yield (III).

Objectives

The project I'm involved in aims to:

1. Understand and quantify the physiological damage caused by *T. urticae* to cotton at the leaf and plant level and relate this to effects at the crop level.
2. Investigate the possible interaction of abiotic factors (Figure 1) with mite populations and cotton.

What is Known About Mite Physiological Damage to Plants?

Mites mainly feed on the underleaf surfaces of cotton, penetrating the outer leaf layer to feed on the palisade and spongy mesophyll cells (upper and middle cell layers) within the leaf (figure 2). These cells are the main site of photosynthesis (the conversion of atmospheric carbon dioxide (CO_2) to organic carbon which gives plants energy). They contain chlorophyll, a green pigment that absorbs light energy which drives the photosynthetic process. So mite feeding detrimentally effects photosynthesis and several other important leaf physiological processes.

Leaf tissue regulates the diffusion of CO_2, which the plant requires for photosynthesis, into the leaf via stomates (figure 2). Stomata are minute openings in the outer layer of the leaves, the opening and closing of which is controlled by bordering guard cells. Past research has found that dehydrated palisade and mesophyll cells, resulting from mite damage, cause a lack of turgor (ie. water pressure) in the guard cells which in turn results in stomatal closure. Thus, the conductance of CO_2 is greatly reduced. Stomatal closure is also influenced by other factors including changing CO_2 concentrations within the leaf and leaf temperature, both of which are also affected by mite feeding damage.

Other physiological processes affected by mite damage include reduced transpiration ie. the evaporation of water through the stomata. Transpiration plays an important role in cooling the leaf and is also important as leaf and fruit expansion requires turgor from regulated water balance. Respiration, the process of using the products of photosynthesis, is also increased.

A leaf subtending to a cotton boll provides about 90% of the boll's nutrients (Duncombe, 1977). Thus damage to leaves in this position would have a major effect on the future crop.

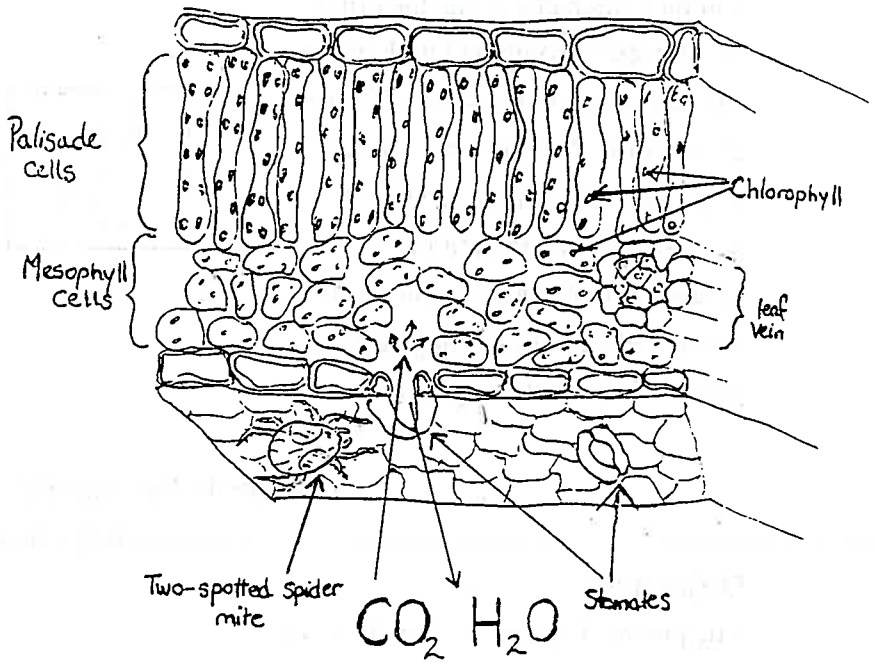

Figure 2: Transverse section of a cotton leaf showing diffusion of CO_2 into the leaf and evaporation of H_2O via the stomata.

Wilson (1993) proposed that reduced photosynthetic capacity in severe cases of mite infestation may heighten competition for assimilates (products of photosynthesis) among sinks such as fruit, leaves and roots, potentially causing fruit shed and limiting the development of bolls.

Research Summary

Field research began for this project at the Australian Cotton Research Institute, Narrabri over the 1995/96 cotton growing season. Experiments were conducted on Deltapine 90 cotton divided into plots of control (no mites) and plots artificially infested with mites. The aim of this initial research was to quantify the effects of cumulative mite damage on major plant physiological processes. Leaf gas exchange measurements were used to determine leaf photosynthetic rate, stomatal conductance, transpiration and leaf temperature using an LI-6400 (LICOR) portable photosynthesis system. Difficulties were experienced using the Licor on heavily mite infested cotton. However figure 3 provides an example of the dramatic reductions in leaf photosynthesis and transpiration which occurred with increasing mite densities.

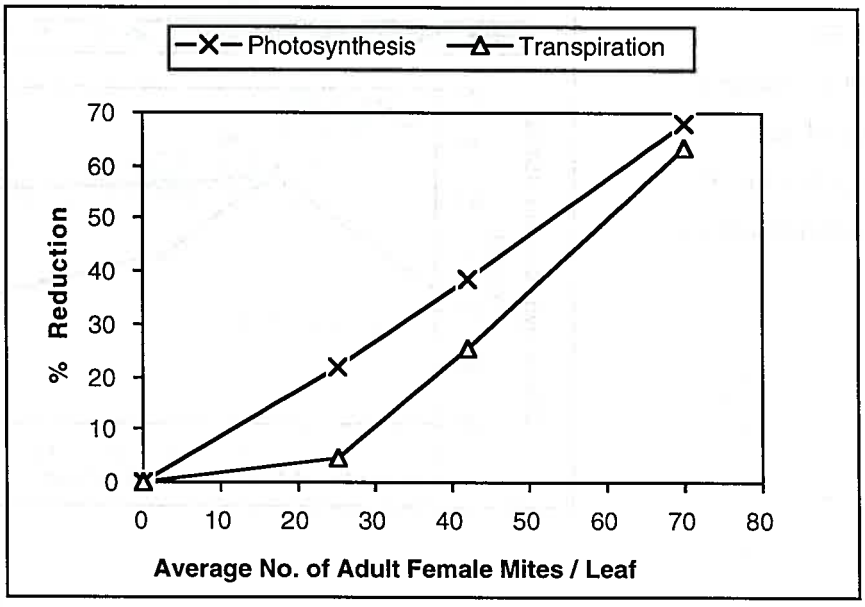

Figure 3: Reductions in photosynthesis and transpiration of cotton leaves with increasing mite density.

As a result of reduced leaf transpiration in the mite infested cotton, leaf temperature increased slightly (figure 4). This may further reduce photosynthetic efficiency because enzymes involved in catalysing the photosynthetic reactions operate optimally within a limited temperature range and may have also been affected by the change in temperature.

the organophosphate insecticide oxydemeton-methyl were >2,000x (Hollingsworth *et al.*, 1994). Such levels of resistance invariably lead to complete control failure.

The reduction of chemical use and/or changes in the patterns of chemical use associated with the introduction of transgenic cotton may raise the pest status of cotton aphid in Australia. Reports have already been received that cotton aphid caused problems late in the growing season in some transgenic cotton plots. Those plots required several insecticide sprays.

In Australia it has not been proved that reported field control failures of insecticides are due to resistance. Base-line data to detect resistance and determine resistance levels have not been available for cotton aphid. Establishing base-line data for cotton aphid will allow the resistance status of cotton aphid in Australia to be evaluated.

The aims of this project were:

1. To obtain base-line data for pesticides against a susceptible strain(s) of cotton aphid.

2. To conduct an initial evaluation of the current resistance status of field-collected strains of cotton aphid.

MATERIALS & METHODS

Strains tested

Two strains of cotton aphid collected from unsprayed backyards in Sydney were designated "susceptible" and subsequently used to generate base-line data. Four field-collected strains were obtained from cotton growing areas in NSW.

Products tested

Products tested included: Orthene, Lorsban, MetaSystox, Rogor, Endosulfan, Confidor, Lannate, Nuvacron, Folimat, Folidol, Pirimor, Curacron, Ekatin, Talstar, Karate, Ekalux, Helthion, Decis Forte, triazamate and CGA-140408.

Bioassay method

Aphids were tested using methods similar to that described in Herron *et al.*, (1996) for western flower thrips. Briefly that required excised cotton plant leaf disks to be placed onto liquid but still cooling agar in a Petri dish. When the disks had cooled, batches of aphids were transferred to the Petri dishes and then sprayed with aqueous insecticide emulsions by Potter spray tower. Petri dishes were then covered with clear cling wrap and mortality was assessed after 24 hours. Probit regressions were then calculated using Probit 5 for Windows (Gillespie, 1995). Calculated LC99.9 values for the more tolerant of the "susceptible" strains was used as a discriminating concentration. This discriminating concentration was then used to screen field-collected strains for resistance. Not all aphid strains were tested against all chemical products.

RESULTS and DISCUSSION

The two reference susceptible strains showed less than 3 fold variation in response at the LC99.9 level. The data provide a good basis for the continuing study of cotton aphid in Australian cotton. There is strong evidence that pyrethroid and endosulfan resistance is present but more work is needed to validate the standard discriminating-doses used in this study. Research should now concentrate on monitoring a large number of field-collected strains from a range of cotton growing areas to determine the variability in response to key chemicals. Specifically, the variability in response of pyrethroids and endosulfan to cotton aphid requires quantification and, based on overseas experience organophosphate and

Table 1. Theoretical discriminating-concentrations (LC 99.9**) for two "susceptible" strains of cotton aphid plus prima-facia resistance detection in selected field strains.

Chemical	LC 99.9 (% ai) Susceptible A	LC 99.9 (% ai) Susceptible B	Prima-facia Resistance
Orthene	0.045	0.020	no
Lorsban	0.0026	0.0048	no
MetaSystox	0.0014	0.0019	no
Rogor	0.0051	0.0036	no
Endosulfan	0.015	0.085	yes
Confidor	0.0004	0.0013	no
Lannate	0.0035	0.0087	no
Nuvacron	0.0005	0.0013	no
Folimat	0.0011	0.0017	no
Folidol	0.0057	0.0013	no
Pirimor	0.0009	0.0028	no
Curacron	0.0022	0.0015	no
Ekatin	0.0037	0.0066	no
Talstar	0.00005	0.0001	yes
Karate	0.00003	0.00005	yes
Ekalux	0.0006	0.0013	*
Helothion	0.0045	0.0041	*
Hallmark	0.00018	0.00014	*
Decis Forte	0.00026	0.00023	yes
triazamate	0.0022	0.0034	*
CGA-140408	0.0015	0.0025	*

* not tested

** the discriminating concentration was the higher of the two LC99.9 values.

carbamate resistance requires careful monitoring. Finally, resistance management of cotton aphid needs to be considered under the specific insecticide use requirements of transgenic cotton. If not, overseas experience clearly indicates that overuse of organophosphate or carbamate aphicides in cotton will lead to resistance and control failure.

ACKNOWLEDGEMENT

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