THE EFFECTS OF APHIDS ON PHOTOSYNTHESIS IN COTTON

Simone Heimoana[1, 3], Lewis Wilson[1,3], Greg Constable[1,3] and Robert Fletcher[2]
[1] CSIRO Plant Industry, Locked Bag 59, Narrabri, NSW, 2390
[2]School of Food and Land, The University of Queensland, Gatton, QLD, 4345
[3]Cotton Catchment Communities Cooperative Research Centre

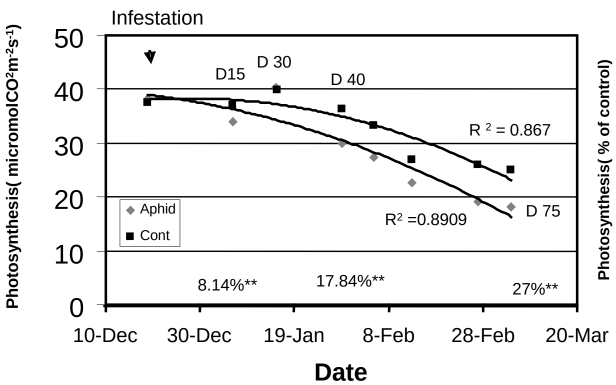
In Australia, aphids usually occur in cotton later in the season when their prolific production of honeydew contaminates lint during boll opening. However, with the recent advances in genetically modified Bt cotton varieties, which have enabled growers to use less pesticide, aphids and other sucking pests have become more important, especially if they appear early in the season.

The detrimental effect of aphid feeding on plant growth has been reported from various crops around the world (Atakan and Ozgur, 1996; Hille Ris Lambert, 1970; Kimmins, 1986; Lowe, 1967; Miles, 1987). We first studied the effects of aphid feeding on cotton and dry matter production in 1999/2000. Prolonged feeding by heavy aphid populations significantly decreased cotton and dry matter production and raised questions about how aphids caused these effects. Contamination of leaves by honeydew, salivary effects and assimilate removal could all be factors. We also noticed that aphid infested plants often grew poorly, even before the level of honeydew production was very high, and speculated that perhaps aphids also affected the photosynthetic rate of cotton. Since it is known that the removal of leaf sugars (such as occurs during aphid feeding) can increase the concentration of sugars in the leaf and thereby give negative feedback to photosynthesis (Blechschmidt-Schneider, et al., 1989; Franck, et al., 2006), we decided to consider this factor first. Our subsequent work investigated any relationships between aphid populations and plant photosynthetic response; how many aphids would be required to elicit a response; and the duration of the response to become measurable.

Do aphids reduce photosynthesis?

The first experiments involved cotton crops artificially infested with aphids by mid-December. Photosynthesis was measured using a LiCor 6400 IRGA (Infrared gas analyser), which measures the exchange of gases through the leaf pores and relates this to photosynthetic activity. Measurements were taken prior to infestation, and then at approximately weekly intervals for 14 weeks. Photosynthesis was measured on five leaves per plot, which were located at node 3-4 from the terminal in both infested and control plots (+/- Aphids) measuring a total of 20 leaves per treatment over 4 replications. The measured leaf was removed for assessment of aphid numbers and leaf area.

Results showed a gradual decline of photosynthetic activity over time in both control and aphid infested plants (Fig.1). The reduction in photosynthesis in the control leaves was due to age while the significantly accelerated rate of decline in the infested leaves corresponded with rising aphid populations. This effect was apparent 15 days after infestation and persisted for the remainder of the experiment. The initial decline from control was 8.14% and had reached 17.84% by day 40. By the end of the experiment, infested plants were photosynthesizing 27% less than control plants.



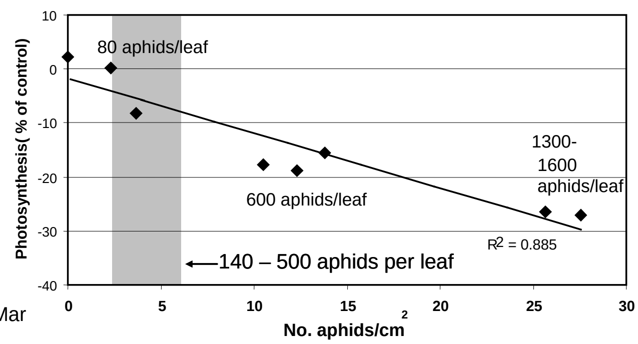


Figure 1: Effect of aphids on photosynthesis in cotton over time

Figure 2: Percentage reduction in photosynthesis vs aphid density (average leaf size = 72cm^2)

At the peak of infestation, aphid numbers had reached 1500 aphids/leaf. We found a strong relationship between increasing aphid population density (expressed as aphids per cm^2) and reduction in photosynthesis, expressed as the relative reduction in photosynthesis compared with undamaged leaves (Figure 2). Subsequent experiments with lower numbers of aphids suggested that the initial effect of aphids on photosynthesis could begin at 1 – 7 aphids per cm2 or about 140 – 500 aphids per leaf. This could be influenced by other factors such as plant age and environmental conditions or water stress, but raised the issue of how many aphids would be required to feed for how long before photosynthesis was affected.

Aphid Density x Time

In order to better define the shaded area on Figure 2 where photosynthesis reduction first occurred, a number of aphid density x duration experiments were set up in the field by placing 0, 50 or 100 aphids per leaf (main stem leaf 3 or 4 below the terminal) and covering them in mesh bags to avoid predation. Control leaves were similarly covered and aphid populations were left to develop. There were no significant pre-treatment differences. Photosynthesis was measured every 4-5 days.

Figure 3 shows that by day 8 from infestation photosynthesis was significantly decreased for both the 50 and 100 aphids/leaf treatments but there was no difference between the two aphid densities. It is important to note that aphid numbers increased throughout the experiment, the 50 stocking rate increased to 75 and the 100 to 195. After 16 days aphids were removed, but leaves did not recover, suggesting lingering effects of aphid feeding.

A second round of experiments including 25 aphids/leaf showed similar results (Figure 4).There were no significant differences pre-treatment and for the first measurement at 4 days. By day 7, the 25 and 100 aphids/leaf treatments had significantly lower photosynthesis than the control treatment while the measurement for 50 aphids/leaf was only just outside significance. For the next week, the 50 and 100 aphid/leaf treatments generally remained at this lower level of photosynthesis while the 25 aphids/leaf treatment behaved more like the control treatment. By day 13, both the 50 and 100 aphids/leaf treatments had lower photosynthesis than the control treatment and the 50 aphids/leaf treatment was also significantly lower than the 25 aphids/leaf treatment. At that stage all aphids were removed and leaves were measured after 24 hours. The 50 and 100 aphids/leaf treatments still had significantly lower photosynthesis than the control treatment, but they were not different from the 25 aphids/leaf treatment. Seven days after removal of aphids, there were no significant treatment differences.

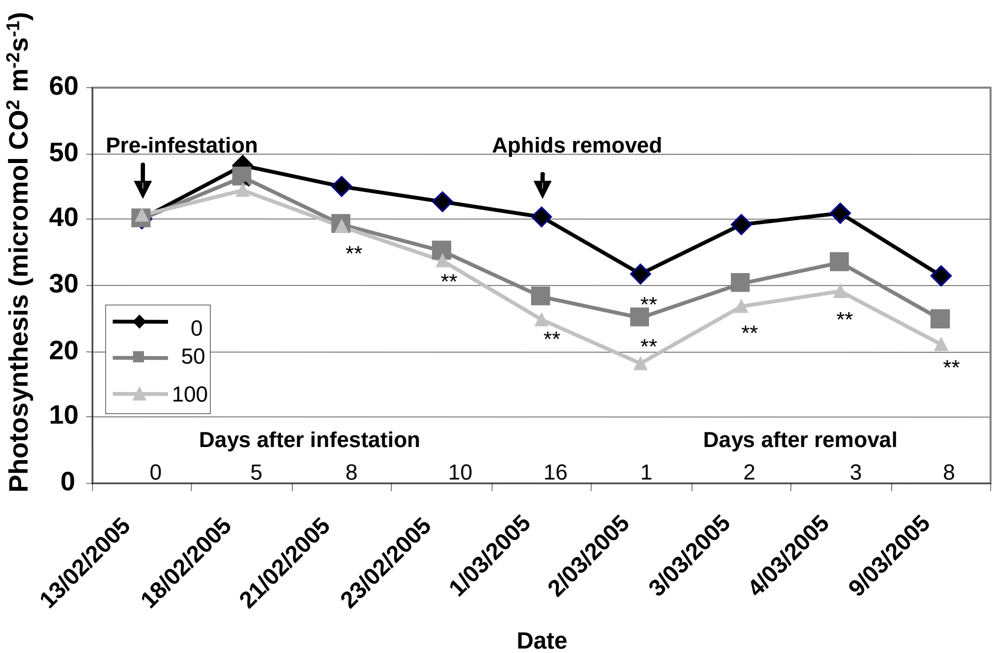


Figure 3: Photosynthetic response of cotton to varying densities of aphids – Experiment 1
* asterisk signifies significance at P=0.05

The second experiment confirmed that there was no difference between 50 and 100 aphids/leaf, indicating that once the infestation reaches a certain population threshold, photosynthesis will decline, but not necessarily at a faster rate. However, assessing the effect of population growth is not straightforward because the designated number of aphids/leaf generally increased throughout the duration of the experiment. Some 25 aphids/leaf treatments ended up with over 100 aphids within a few days, while more aphids occurred on average in the 50 aphids/leaf treatment than in the 100 aphids/leaf treatment

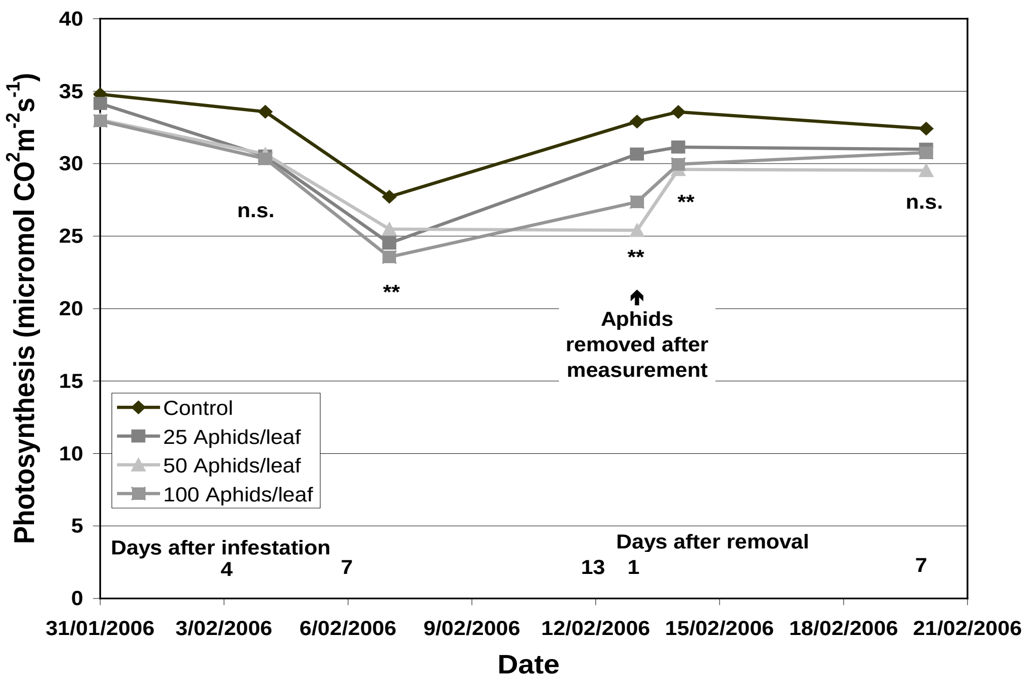


Figure 4: Photosynthetic response of cotton to varying densities of aphids – Experiment 2
* asterisk signifies significance at P=0.05

To eliminate the variability of treatment effects for individual leaves, data from the second experiment was examined again and the relationship between aphid numbers and time was expressed as cumulative aphid days. Figure 5 shows the days at which photosynthetic measurements were taken while infestation progressed. No significant effects were seen on day 4, but by day 7, some of the treatments were showing a significant effect (25 and 100 aphids/leaf, triangles marked with an asterisk). By day 13, the 25 aphids/leaf treatment, which increased at a slower rate, was not significant anymore, but the 50 and 100 aphids/leaf treatments (stars marked with an asterisk) moved into the zone where the effect on photosynthesis became much more consistent, i.e. between 1100 and 1900 aphid days

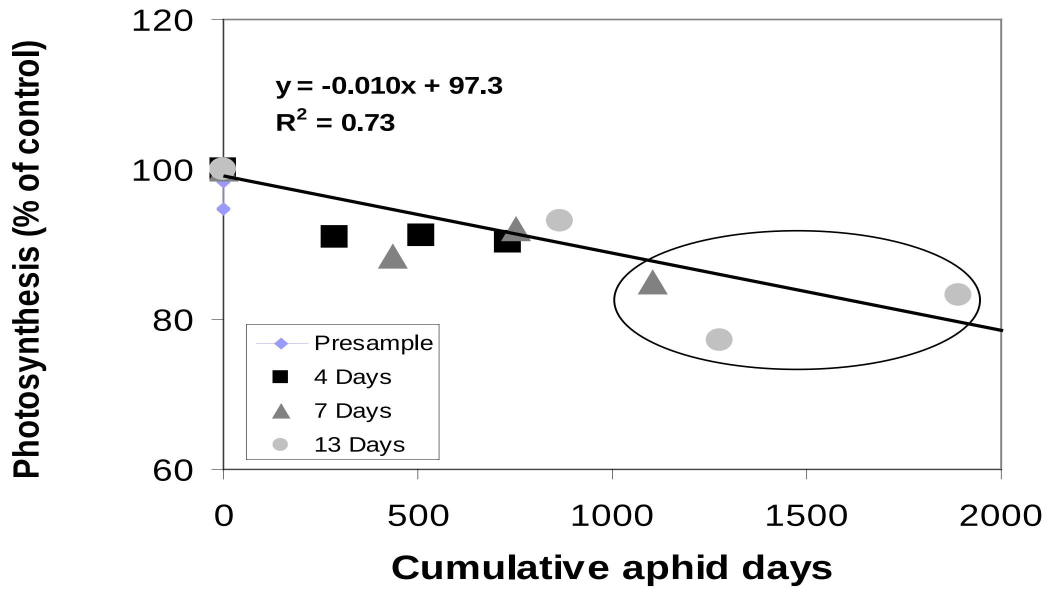


Figure 5: Relationship between relative photosynthesis and cumulative aphid days

Conclusion

Our results confirm that aphid populations can cause significant reductions in the photosynthetic rate of cotton plants, and this could at least partially explain the effects of aphids on plant growth and final yield. There was a strong relationship between aphid density and reductions in photosynthesis, indicating a cumulative effect from aphid feeding. Detailed experiments suggest that aphids begin to affect photosynthesis of leaves once the aphid population on the leaf exceeds about 1000 aphid days. Future research will evaluate if aphid damage affects the vascular systems in cotton leaves. Reduced transport of phloem or reduced phloem pressure could allow photosynthate sugars to accumulate in leaves creating negative feedback on photosynthesis. Even after removal the effect on photosynthesis remained, which indicates that a possible blockage of phloem elements could maintain the higher leaf sugar concentration.

Acknowledgements

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