Development of IPM Strategies and Tools for Western Flower Thrips (Frankliniella occidentalis) in Hydroponic Lettuce

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(August 31 2011)

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Submitted August 31 2011

The purpose of this report is to summarise a series of trials which have developed tools for managing western flower thrips (WFT) and, therefore, the serious disease tomato spotted wilt virus (TSWV) in hydroponic lettuce crops. Tools include several reduced risk pesticides, two predatory mite species, and a number of cultural controls such as hygiene, use of yellow sticky ribbon, and improved spraying techniques. This research has demonstrated that combinations of these techniques can provide control equal to, or better than, control achieved with conventional pesticides.

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Media Summary

Since its initial detection in 1993, western flower thrips (WFT) has become a key pest of hydroponic lettuce in Australia. The insect causes feeding damage and spreads disease, particularly the serious tomato spotted wilt virus (TSWV). It can rapidly develop resistance to pesticides, making chemical control difficult. Hydroponic lettuce growers have therefore had limited options for managing this pest.

This project has developed tools for growers to use as part of an integrated pest management (IPM) strategy for controlling WFT in lettuce. Adopting these methods not only reduces use of chemicals in general, but also helps maintain the effectiveness of existing chemicals for strategic use in the future. Several reduced risk pesticides were tested. While these chemicals were found to provide good control of WFT, comparable with industry standard treatments, they had little effect on predatory mites and could safely be used within an IPM strategy.

Two predatory mite species, *Transeius montdorensis* (Monty) and *Geolaelaps aculeifer*, *were* shown to be effective at controlling WFT, either alone or, for the best results, released together. The mites were able to greatly reduce WFT populations in greenhouses. An on-farm trial demonstrated that, even in the more variable outdoor environment, biological control of WFT was as good or better than that achieved with conventional pesticides. Both species of predatory mites are commercially available for use in crops and the work during these trial shows this new and exciting use is available for hydroponic lettuce growers.

There was previously no real evidence that improving hygiene in hydroponic lettuce crops reduced pests and diseases. This project has demonstrated that a small amount of diseased material inside a greenhouse can result in rapid spread of TSWV to uninfected plants. In one trial over 50% of lettuces were infected after only 23 days. A survey of hydroponic growers found that most have several weeds species present that are potential host of WFT and / or TSWV. Controlling these weeds and removing diseased plants could have major benefits in reducing pest and disease pressure. Many growers use tractor driven blowers to apply pesticides to their crops. These were found to provide poor crop coverage compared to boom spray, knapsack or ute-pack sprayers. Incomplete coverage not only can fail to control a pest, it increases the chance of resistance. Use of blowers is not recommended as a result.

This project has evaluated valuable tools for better managing WFT in hydroponic lettuce crop, including reduced risk ('soft') pesticides, biological control agents and cultural methods. Innovative and novel uses of biological control agents and existing cultural practices were also developed. Growers have participated in on-farm demonstration trials, workshops and training in IPM techniques. Whilst the reduced risk pesticides will require support from their manufacturers to be registered for use in lettuce crops, the biological control agents and cultural methods are available for use immediately and will lead to increased control of these important pests.

Hydroponic lettuce growers should be supported and trained in the removal of pesticide residues from cropping areas and training in compatible chemicals so that they can take advantage of the novel use of the biological control agents. In addition, the use of sticky ribbon should be trialled on a larger scale and the routine use of blowers to apply pesticides in hydroponic lettuce should be actively discouraged. Insufficient coverage is being provided by this strategy with high risks of both ineffective control and increased pesticide resistance. Implementing IPM requires time, attention, knowledge and commitment. However, as this project has demonstrated, the results can be excellent.

Technical Summary

Since its initial detection in 1993, western flower thrips *Frankliniella occidentalis* (Thysanoptera: Thripidae) (WFT) has become a key pest of hydroponic lettuce in Australia. The insect causes damage due to feeding and egg laying in plant tissues and is a major vector of disease, particularly the serious tomato spotted wilt virus (TSWV). WFT can rapidly develop pesticide resistance (Colomer *et al*, 2011), reducing options for chemical control. Hydroponic lettuce growers have therefore had limited options for managing this pest.

This project has developed tools for growers to use as part of an integrated pest management (IPM) strategy for controlling WFT in lettuce. Other methods include practicing good farm hygiene in and around the crops to limit the movement of thrips from non-crop hosts, monitoring regularly and practicing good record keeping, the use of a rotating spray regime that is applied with adequate coverage and pesticides that are compatible with biological control agents used and, where possible, screening the crop to prevent the introduction of adult thrips flying in. Adopting these methods can improve overall control, reduce reliance on a limited range of pesticides and maintain the effectiveness of existing chemicals for strategic use in the future.

Several reduced risk pesticides that are currently unavailable to hydroponic lettuce growers were tested. While these chemicals were found to provide good control of WFT, comparable with industry standard treatments, they had little effect on mortality, egg laying and egg hatch of predatory mites so could safely be used within an IPM strategy. Providing this information to registrants of the pesticides that were evaluated may influence their decision to register these products for use in hydroponic lettuce crops.

Two predatory mite species - *Transeius montdorensis* and *Geolaelaps aculeifer* - were shown to be effective at controlling WFT, either alone or, for the best results, released together. The mites significantly reduced all lifestages of WFT in greenhouses. An on-farm trial demonstrated that, even in the more variable outdoor environment, control of WFT with predatory mites was as good or better than that achieved with conventional farm management practices focussed on chemical control.

There is little scientific evidence in the literature databases that shows that improving hygiene in hydroponic lettuce crops reduces pests and diseases. This project has demonstrated that a small amount of diseased material inside a greenhouse can result in rapid spread of TSWV to uninfected plants. A larger scale trial demonstrated that over 50% of lettuces were infected after only 23 days. A survey of hydroponic growers found that most have several weeds species present that are potential host of WFT and / or TSWV. Controlling these weeds and removing diseased plants could have major benefits in reducing pest and disease pressure.

Many thrips, and in particular *F. occidentalis*, quickly develop pesticide resistance to a variety of pesticides commonly used in agriculture to manage the pest (Herron *et* al., 1996). Incomplete coverage not only can fail to control a pest, it increases the chance of pesticide resistance developing. Many growers use tractor driven blowers to apply pesticides to their crops. These were found to provide only 20-50% crop coverage compared to 90-100% coverage by other methods. It is recommended that growers consider changing to boom or hand held sprayers (ute-pack or knapsack) as a result. Whilst no pesticide resistance testing was carried out on the WFT populations in this study, the mechanism is well understood and the principles of spray coverage are believed to contribute to resistance management.

This project has evaluated valuable tools for better managing WFT in hydroponic lettuce crop, including reduced risk ('soft') pesticides, biological control agents and cultural methods. Innovative and novel uses of biological control agents and existing cultural practices were also developed. Growers have participated in on-farm demonstration trials, workshops and training in IPM techniques. Implementing IPM requires time, attention, knowledge and commitment. However, as this project has demonstrated, the results can be excellent.

This project has improved understanding of western flower thrips and the associated disease, tomato spotted wilt virus within hydroponic lettuce production systems. Cultural management strategies, reduced risk pesticides and biological control agents are now available to growers to help mitigate the effects of the insect pest. Whilst the reduced-risk pesticides are yet to be registered in these crops, the biological control agents are available now (http://goodbugs.org.au).

The companies producing the reduced-risk pesticides HGW86, Agri50NF and Biocover are actively encouraged to seek registration of these products in hydroponic lettuce crops. These pesticides have high efficacy and are compatible with integrated pest management and biological control. For biological control options, hydroponic lettuce growers should be supported and trained in the use of the biological control agents *Transeius montdorensis* and *Geolaelaps aculeifer* to ensure they are used effectively in control of WFT. This should include removal of pesticide residues from cropping areas and training in compatible chemicals.

High traffic areas of WFT on farms should be identified and the use of sticky ribbon trialled on a larger scale. Barriers of sticky ribbon should be installed in such areas to intercept adult WFT. When application of pesticides is required, routine use of blowers to apply pesticides in hydroponic lettuce should be actively discouraged. Insufficient coverage is being provided by this strategy with high risks of both ineffective control and increased pesticide resistance.

A series of workshops should be presented to growers to highlight the findings and educate them on how to use the tools developed in this project. Historically (HAL Project Number VG03098 for example) it has been shown that one-on-one help for growers has resulted in increased uptake and adoption and this should also be considered.

Introduction

Western flower thrips (WFT) *Frankliniella occidentalis* originates from the western USA and was first found in Western Australia in 1993. It has spread to all states and most production areas since.

WFT is a significant pest because it is a vector of tomato spotted wilt virus (TSWV) that affects key vegetable crops grown in the Sydney Region, such as tomatoes, lettuce, cucumbers, potatoes, and capsicum. WFT is more of a problem than other thrips species because it develops resistance to pesticides easily, hence there are few chemical options to control it.

WFT eggs are laid into soft plant tissue. Within a few days eggs hatch into a wingless juvenile or larval stage. Immature thrips are pale yellow, thin, wingless and up to 1 mm in length.

Thrips have two feeding larval stages followed by non-feeding pre-pupal and then pupal stages that tend to hide in soil crevices or within foliage. Winged adults emerge from the pupae to mate and feed. Adults are also thin, with yellowish head and darker abdomen. They are about 1.5-2 mm in length, with two feathery wings. The length of the life cycle and life expectancy of the adults depend on temperature and food quality. At 30°C the life cycle is approximately 12 days while at 20°C it is 19 days. WFT breeds on a wide range of flowering plants including weeds, vegetable crops and fruit trees.

WFT feeding can cause scarring and deformation on leaves and fruit, with seedlings and soft tissue particularly prone to feeding damage. Products particularly susceptible to scarring include capsicums, cucumbers and beans. WFT larvae must feed on a tomato spotted wilt virus TSWV-infected plant to acquire TSWV. Once a larva has acquired the virus, TSWV will multiply within the larva. When an infected larva reaches adulthood it can fly to a new plant, transmitting the virus as it pierces the plant cells and sucks the contents. The virus does not pass through the egg stage so each succeeding generation of WFT must re-acquire the virus as larvae feeding on TSWV-infected plants. Uninfected adult thrips cannot acquire the virus.

TSWV is a tospovirus that has become one of the most wide-spread and damaging viruses affecting vegetable crops in Australia. TSWV was first described in Australia in 1915 and has been a sporadic problem since. The arrival of the very efficient vector WFT has seen an increase in the seriousness of the disease, particularly in hydroponic and covered systems. In recent years there has been anecdotal evidence suggesting that TSWV has been responsible for the destruction of up to 80-90% of hydroponic lettuce in production at individual farms in the Sydney Basin.

TSWV is also transmitted in vegetables by tomato thrips (*Franklienella schultzei*) and onion thrips (*Thrips tabaci*). Melon thrips (*Thrips palmi*) is also a vector of TSWV but is not widespread in NSW. Plague thrips (*Thrips imaginis*) and other non-host thrips cannot acquire the virus, nor can other insects such as aphids. TSWV is not spread in seed or via mechanical damage although it can be spread through cuttings used for plant propagation. Once a plant is infected with TSWV it cannot be cured, so prevention or use of tolerant varieties, if available, are the only management options.

Many hundreds of plants (>900) are TSWV hosts, most being in the Solanaceae, Asteraceae or Fabaceae. Some show symptoms and some do not. TSWV causes significant damage to solanaceous vegetables such as tomatoes, potatoes and capsicums, but also to lettuce and a wide range of herbs and ornamental crops, whereas cucumber infections are symptomless.

Common weed hosts of TSWV (and WFT) include amaranth, cape weed, pigweed, mallows, blue heliotrope, fat hen, purple top, shepherd's purse, nightshades, Scotch thistle and sow thistle. Not all plants that are infected by TSWV will show symptoms. Crops that are susceptible will tend to show symptoms on the new developing foliage after infection.

Some varieties of capsicums and tomatoes are resistant to TSWV although strains of TSWV that break the resistance can develop in areas of high TSWV pressure. For resistant varieties it is still important to reduce the virus pressure through weed management and other sanitation measures.

Hydroponic lettuce growers have limited options for controlling WFT with the pest species able to quickly develop pesticide resistance to a variety of pesticides commonly used in agriculture to manage the pest (Herron *et* al., 1996). Reducing reliance on conventional pesticides would retain the efficacy of these chemicals for strategic future use. An integrated pest management (IPM) strategy involving effective, commercially available biological control agents and reduced-risk chemicals is therefore needed urgently for this industry.

The first major strategy in managing WFT is to maintain good hygiene practices. This practice assists in the mitigation of pesticide resistance as removing weeds may cause a reduction in pest pressure which leads to a possible reduction in the need to manage pests using pesticides. This reduction in pesticide use in turn reduces the selection pressure for the pest population to develop pesticide resistance. Weeds should be removed or controlled, crop debris destroyed, purchase seedlings from a reliable or accredited supplier, avoid the introduction of new plant material during a crop and attempt to achieve control early in the lifecycle of the pest. It is important during all stages of the crop to monitor and check for the presence of WFT and ensure correct identification as many species of thrips can be confused with WFT.

If spraying is necessary, three applications is recommended due to only the adult and larval stages of WFT being susceptible and the eggs and pupae often being protected from sprays. A three spray regime helps to ensure that the eggs have been given a chance to hatch into larvae and for pupae to develop into adults, thereby becoming susceptible to applications. The higher the temperature, the shorter the interval between sprays should be.

In order to reduce the selection pressure for pesticide resistance, three consecutive sprays of the same chemical should be applied before alternating to a different chemical group for the next series of sprays. These sprays should be used in conjunction with other management techniques such as hygiene as detailed above. Pesticide resistance develops in a pest population when a single application of pesticide removes susceptible individuals leaving behind those that have a tolerance to the pesticide. Over time, these tolerant individuals breed with the remaining population and gradually increase the tolerance of the population as a whole, leading to resistance. These strategies effectively reduce the selection pressure for resistance by using an alternate pesticide to eliminate those tolerant individuals.

Current biological control agents for WFT are limited to Laelapid and Phytoseiid mite species. Unfortunately, these species are extremely sensitive to minute quantities of chemical residues (Croft 1991). Even if residues do not kill the mites, their lifespan and fecundity are reduced and they are less able to predate on WFT. Developing strategies to protect beneficial insects in the greenhouse environment, including reduced risk chemicals, is vital to the efficacy of IPM programs.

Although WFT has been confirmed in lettuce crops on the North Coast of NSW, it has not yet been found in the dryer, inland vegetable growing areas. These inland areas have a variety of virological diseases present in vegetable and other crops. Were WFT to spread inland, it is likely to spread these diseases, infecting neighbouring lettuce crops. The industry is therefore extremely concerned about the spread and control of WFT.

Literature and extension material produced during this project included a symposia and workshop on pest and disease management of field and hydroponic lettuce held at the University of Western Sydney Hawkesbury conference centre. Several presentations were given at national and international conferences including the combined Australian and New Zealand Entomological Societies Conference in New Zealand. Some of the literature and presentations to industry and the scientific community can be found in Appendix A.

This project has developed improved management strategies for WFT in lettuce, using combinations of crop hygiene, biological control agents and reduced risk chemicals. As growers adopt these recommendations there will be a reduction in pesticide use across the industry which will promote longevity in the efficacy of registered products as selection pressure for resistance will be reduced.

Materials and Methods

Reduced Risk Chemicals

Efficacy of HGW86 against Western flower thrips

Introduction

Few IPM compatible pesticides are available for hydroponic lettuce systems. HGW86, a new reduced-risk pesticide being developed by DuPont could prove effective for this purpose. This pesticide would be available to be used as part of a pesticide resistance management plan as it is a different mode of action to spinosad – an active ingredient commonly used for the management of western flower thrips (WFT) to which individual populations quickly develop resistance to.

Although not currently registered for use in hydroponic lettuce systems, it was hoped that efficacy data would advance this process, making this chemical available for hydroponic lettuce growers. The responsibility of registration of this pesticide lies with the producer and these data will provide the efficacy information required for registration. Ultimately, however, it is the producer that is required to seek registration.

The aim of this trial was to determine if HGW86 could be used in management of WFT. Two spray rates of HGW86 were tested against WFT on hydroponic lettuce and compared to the current industry standard, Spinosad.

Method

Lettuce seedlings (cv. “green oakleaf”) were ordered from a known supplier with the request that no pesticides were applied to ensure that WFT populations could establish on the plants.

Nutrient film technique (NFT) hydroponic system benches were set up in an experimental greenhouse (approx $25m^2$) and ran at an ideal EC of 1.4-1.5 and pH of 6.0-7.0. Seedlings were planted at the rate of one seedling/hole (Figure 1).

Figure 1: Single lettuce seedlings planted in Nutrient Film Technique channels

Ten WFT larvae were released by soft bristled paintbrush onto the upper leaves of each lettuce seedling. Thrips numbers were assessed on seedlings during the pre-treatment count to ensure that numbers were uniform across the replicates. The trial began once the population was uniformly distributed across the replicates,

Treatments consisted of:

1. HGW86 0.05 (0.5mL/L)
2. HGW86 0.075 (0.75mL/L)
3. Positive control (spinosad [0.8mL/L])
4. Negative control (water).

Treatments were applied weekly for three weeks. A handheld sprayer was used to spray to the point of incipient runoff and a removable barrier was used between the plants while spraying to minimise the chance of contamination. Treatments were randomised and blocked for data analysis (Figure 2) and repeated twice for additional replication in time.

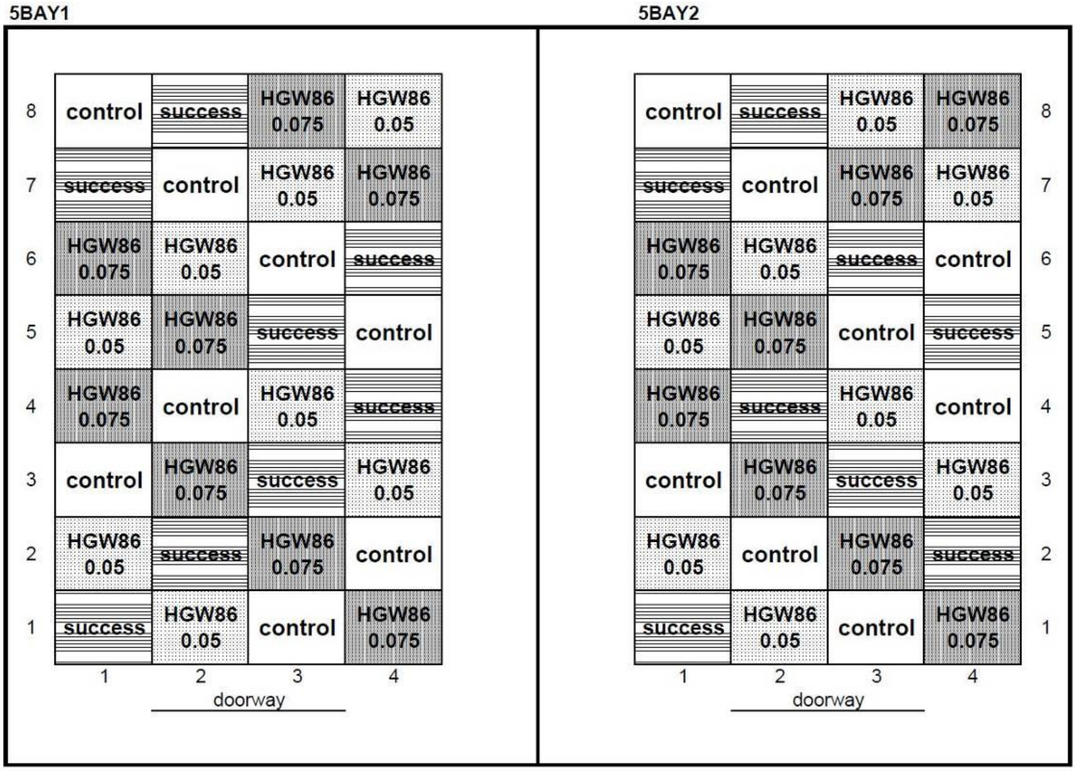


Figure 2: Randomised design for treatment applications

As the plants grew, some leaves were trimmed to prevent lettuces of different treatments touching, allowing WFT larvae to move between plants (Figure 3). Trimmed leaves were laid back over the lettuce, allowing WFT larvae to return onto the plant.

Figure 3: As lettuce plants grew, leaves that were about to touch were trimmed to prevent movement of thrips from one plant to another.

Thrips numbers on each plant were counted on the day immediately preceding spray applications. At the end of the trial whole lettuces were harvested and rinsed. The water and debris was passed through a series of three sieves (250, 140, 105 microns). Thrips were collected in the 105 micron sieve and could then be counted using a compound microscope.

Compatibility of HGW86 with *Transeius montdorensis*

Introduction

HGW86 is a new reduced-risk pesticide being developed by DuPont. Because of the paucity of pesticides that are IPM compatible in a hydroponic lettuce system, side effect data was developed for DuPont to complement the efficacy data developed.

The experiment sought to determine what, if any, side effects and non-target effects the product has when used in conjunction with *T. montdorensis*.

Methods

A bioassay looking at the side effect of the reduced risk chemical HGW86 on *T. montdorensis* was undertaken at Gosford using the Potter spray tower. Bioassay methodology used was the same as previously described for Agri50NF.

Five rates of HGW86 were tested against a negative control:

1. standard rate (0.075 $ml.L^{-1}$)
2. 1/4 rate (0.019 $ml.L^{-1}$)
3. 1/2 rate (0.038 $ml.L^{-1}$)
4. 3/2 rate (0.113 $ml.L^{-1}$)
5. 7/4 rate (0.132 $ml.L^{-1}$)
6. distilled water

This bioassay was temporally replicated three times.

Combining HGW86 with *Transieus montdorensis* for control of WFT in hydroponic lettuce

Introduction

It has been found in previous trials that the novel pesticide HGW86 at the rate of 0.075% can provide an effective control of WFT similar to or better than the use of the industry standard chemical, spinosad. The phytoseiid predatory mite, *T. montdorensis,* can also be used to manage WFT in greenhouse crops.

This trial aimed to determine the best practices for application of HGW86 in combination with the predatory mite *T. montdorensis*, for the management of WFT in a hydroponic lettuce crop.

Methods

Lettuce seedlings (cv. "green oakleaf") were ordered from a known supplier with the request that no pesticides were applied to ensure that WFT populations could establish on the plants.

Nutrient film technique (NFT) hydroponic system benches were set up in an experimental greenhouse and ran at an ideal EC of 1.4-1.5 and pH of 6.0-7.0. A total of four blocks were set up, with four growing channels in each block and 15 lettuce plants per channel. Approximately 15 WFT adults and 15 larvae were released to each plant and allowed to establish before the treatments were applied.

Four treatments were randomly allocated in each block:

1. HGW86 ($0.75 ml.L^{-1}$)
2. *T. montdorensis* (five adults/plant)
3. HGW86 ($0.75 ml.L^{-1}$) + *T. montdorensis* (five adults/plant)
4. negative control (distilled water).

T. montdorensis was released only once, at the start of the trial, while application of HGW86 was repeated weekly for 3 weeks.

Thrips numbers on each plant were counted before the first spray then numbers of WFT and mites were counted weekly before sprays were re-applied. At the end of the trial whole lettuces were harvested and rinsed. The water and debris was passed through a series of three sieves (250, 140, 105 microns). Thrips were collected in the 105 micron sieve and could then be counted using a compound microscope.

Compatibility of Agri50NF with *Transeius montdorensis*

Introduction

Many factors can affect the ability of biological control agents to manage pest numbers below the economic injury threshold. Perhaps the most important is pesticide use. Only reduced-risk, IPM compatible pesticides that minimise impact on non-target organisms can be used in conjunction with biological control agents.

Several trials were conducted to identify reduced-risk pesticides that were both effective and compatible with commonly used biological control agents. This trial used a laboratory-based bioassay to quantify the side effect of the reduced risk chemical Agri50NF on the predatory mite *T. montdorensis*.

Methods

Mature female *T. montdorensis* adults were used for the bioassay. To ensure the females tested were the same age, *T. montdorensis* eggs were isolated from soybean leaves (from the DPI *T. montdorensis* culture) seven days before the bioassay. The eggs were placed in 50mm Petri dishes with agar and bean leaves. Pollen was provided as food.

Five rates of Agri50NF were tested against a negative control:

1. standard rate (3.0 $ml.L^{-1}$)
2. 1/4 rate (0.75 $ml.L^{-1}$)
3. 1/2 rate (1.5 $ml.L^{-1}$)
4. 3/2 rate (4.5 $ml.L^{-1}$)
5. 7/4 rate (5.25 $ml.L^{-1}$)
6. distilled water

Three batches of chemical at each rate were prepared as replicates, and three dishes were set up for each replicate (total = 9 dishes / treatment). Sprays were applied onto leaf discs with agar in the Petri dishes using a standard potter spray tower.

Five female *T. montdorensis* adults were then transferred onto each leaf disc (pollen was provided as food) and the Petri dish was covered with a piece of wrap film that was tightened by a rubber band. Approximately 150 tiny holes were made on the film by a fine insect pin to allow ambient air exchange.

Dishes were then placed inside a plastic box half-filled with saturated salt solution (relative humidity approximately 85%). Dishes with the same replicate number were placed in the same box. The boxes were kept in a 25^{o}C constant temperature incubator.

Adult mortality, number of eggs laid and the number of eggs hatched were recorded two and four days after the spray. On day four, all mobile mites were removed from the dishes. After 7 days the remaining eggs were checked for hatching. The bioassay was replicated three times over time.

Compatibility of Biocover with *Transeius montdorensis*

Introduction

Biocover, a petroleum-based pesticide, primarily kills pests by suffocation. As a contact spray, it has very little or no residual effects. This bioassay was designed to test its contact effect on female *T. montdorensis* adults.

Methods

Methodology used was similar to that previously described for Agri50NF and HGW86, except that female *T. montdorensis* adults were transferred to the leaf discs before the spray was applied. To prevent the escape of adults a slippery material – fluon - was painted by brush on the inside section of the petri dish from above the agar to the wrap film.

Biocover was applied at 0, 0.5, 1, 2, 3 and 3.5% concentrations. Mortality was assessed two and four days after treatment, with a final assessment of egg hatch after seven days. This bioassay was replicated three times over time.

Biological Control Agents

Control of western flower thrips by *Geolaelaps aculeifer* released under the crop

Introduction

Geolaelaps aculeifer is a commercially available predatory mite. Whereas *T. montdorensis* searches for prey on the leaves of host plants, *G. aculeifer* hunts primarily in soil and other media. This trial examined the effectiveness of release of *G. aculeifer* on WFT in a greenhouse situation.

Methods

The trial was undertaken in five small greenhouses (approximately 25m^2) equipped with an NFT system being used to grow hydroponic lettuces. WFT were released into all of the crops such that an established population of adults and juveniles was present on each lettuce plant at the start of the trial. Plastic containers (40L) with a cocopeat media were placed underneath the channels of lettuce to provide a suitable environment for the predatory mites to feed on pupating WFT (Figure 9).

Figure 9: *G. aculeifer* trial showing containers with cocopeat media for application of the predatory mites

Populations of the predatory mite *G. aculeifer* were released into three of the greenhouses in the first week of the trial. The two remaining houses were used as untreated controls. Populations of WFT and predatory mites on the lettuce plants were assessed weekly for four weeks. The trial was replicated temporally three times.

Control of western flower thrips by *Geolaelaps aculeifer* released on the ground

Introduction

The effects of the predatory mite *G. aculeifer* were investigated further following the positive results found in the initial trial. The aim of this trial was to quantify how this soil mite performs when released in cocopeat media on the floor. This would more closely reflect the greenhouse environment encountered in normal commercial practice.

Methods

The trial was conducted in five small greenhouses (approximately 25m^2) equipped with an NFT system and planted with pesticide free hydroponic lettuces. WFT were released into all of the crops such that an established population of adults and juveniles was present on each lettuce plant at the start of the trial. As previously, three greenhouses were used for predatory mite releases, two for untreated control.

At the start of the trial predatory mites *G. aculeifer* were released into cocopeat media located on the floor of the greenhouses (Figure 11). Populations of WFT and predatory mites were assessed weekly for four weeks. The trial was replicated twice over time.

Figure 11: Weed mat was used to retain the cocopeat media that provided an environment for the soil predatory mite, *G. aculeifer.*

Control of western flower thrips by *Transieus montdorensis* in field lettuce conditions

Introduction

The phytoseiid predatory mite *T. montdorensis* has been shown in preliminary trials to be effective for control of WFT in greenhouse lettuce crops. However, it was not known whether this control would persist in the more variable outdoor environment.

This trial aimed to determine the most effect release rate and method to maximise efficacy of *T. montdorensis* under conditions equivalent to those in commercial hydroponic lettuce crops

Methods

This trial was conducted in an open area at Gosford Primary Industries Institute, Narara. Three blocks were constructed, each consisting of five NFT growing channels. Fourteen lettuce plants (cv. green oakleaf) were planted along each channel (Figure 13).

The middle of each channel was covered in entomological sticky trap glue (Tangle-foot). This prevented *T. montdorensis* mites from moving from one side of each channel to the other, effectively dividing each channel into two blocks of 7 lettuces.

Figure 13: Each channel was divided into two blocks (indicated by red brackets), with seven lettuce plants per block.

Approximately 20 WFT adults and 20 larvae were released onto each lettuce plant at the start of the trial. The *T. montdorensis* mites were released only in the first week. Releases were at three rates distributed in three ways as follows:

1. Two *T. montdorensis* mites per plant (total: 14 mites), released onto a single plant (middle) out of the 7 lettuces in the block
2. Two mites/plant (total: 14 mites), released onto every 2^{nd} lettuce in the block
3. Two mites/plant (total: 14 mites), released onto every lettuce in the block
4. Five mites/plant (total: 35 mites), released onto a single lettuce in each block
5. Five mites/plant (total: 35 mites), released onto every 2^{nd} lettuce in the block
6. Five mites/plant (total: 35 mites), released onto every lettuce in the block
7. Ten mites/plant (total: 70 mites), released onto a single lettuce in each block
8. Ten mites/plant (total: 70 mites), released onto every 2^{nd} lettuce in the block
9. Ten mites/plant (total: 70 mites), released onto every lettuce in the block
10. Control (no mites introduced)

Each treatment was replicated three times.

A pre-treatment count of WFT was conducted before the release of *T. montdorensis* at the start of the trial. Populations of WFT and predatory mites were then assessed weekly for three weeks.

Control of western flower thrips using *a* combination of *Transeius montdorensis* and *Geolaelaps aculeifer*

Introduction

While WFT larvae and adults live primarily on leaves and flowers, between these life stages WFT pupates in the soil. Introducing predators that search out WFT in both the upper parts of the plant and the soil underneath would appear a reasonable way to maximise opportunities for predation.

Combining the predatory mites *G. aculeifer* and *T. montdorensis* offers just such an opportunity. While the former primarily hunts for pupae on the ground, the latter searches for adults and larvae on the leaf surfaces. Previous trials testing the effects of these predatory mites in isolation found that, while WFT populations were significantly reduced, control may not be sufficient to prevent economic damage to the crop.

The aim of this study was to determine if the effect of combining these two species of predatory mites could be greater than the effect of either species in isolation. This would then be a commercially viable control strategy for greenhouse growers.

Methods

Trials were undertaken in five greenhouses - three for predatory mite treatment and two for untreated control – and replicated twice in time. Pesticide free lettuces were grown using a hydroponic NFT system as previously described. WFT were released such that established populations of adults and juveniles were present on each lettuce plant at the start of the trial.

Predatory mites *T. montdorensis*, 10 mites per plant, and *G. aculeifer*, 2000 mites per bed covering approximately 12 plants, were released into the greenhouses once only in the first week. *G. aculeifer* mites were introduced onto the cocopeat media floor mat while *T. montdorensis* mites were released directly onto lettuce plants. Populations of all three species were assessed weekly for four weeks.

Control of western flower thrips by *a* combination of *Transeius montdorensis* and *Geolaelaps aculeifer* – *G. aculeifer* applied to lettuce plants

Introduction

While results from the previous trial were encouraging, the release of *G. aculeifer* to the ground under lettuce benches creates practical problems. Creating an environment suitable for the release of the predatory mite may prove troublesome while the multiple release points, when used in conjunction with *T. montdorensis*, requires extra labour.

Releasing the two mite species together would be much easier and time efficient for commercial producers. This trial aimed to determine whether similar control of WFT could be achieved when *G. aculeifer* is released to the base of the lettuce plants, in a combination with *T. montdorensis* for the control of western flower thrips.

Methods

Trials were undertaken in five greenhouses - three for predatory mite treatment and two for untreated control – and replicated twice in time. Lettuces were grown using a hydroponic NFT system as previously described. WFT were released such that established populations of adults and juveniles were present on each lettuce plant at the start of the trial.

Predatory mites *T. montdorensis*, 10 per plant, and *G. aculeifer*, 10 per plant, were released into the greenhouses once only in the first week. Both mite species were introduced near the bases of the lettuce plants. Populations of all three species were assessed weekly for four weeks.

Control of western flower thrips by *Transeius montdorensis* and *Geolaelaps aculeifer* in a commercial lettuce farm

Introduction

The previous trials demonstrated that the predatory mites *T. montdorensis* and *G. aculeifer* could provide excellent control of WFT larvae, pupae and adults within an experimental greenhouse. An additional trial with *T. montdorensis* indicated that this mite could still reduce populations of WFT in an open environment.

The aim of this trial was to test whether the combination of *T. montdorensis* and *G. aculeifer* continued to provide effective control of WFT in hydroponic lettuce under normal commercial conditions.

Methods

Each trial tested four treatments:

1. *T. montdorensis* alone
2. *T. montdorensis* and *G. aculeifer* combined
3. Negative control (no pesticide).
4. Positive control (normal farm practice, chemical control)

The grower's normal management practices utilised a range of conventional chemicals including spinosad (40 ml/100l), dimethoate (80ml/100l), and propineb (200g/100l).

Treatments one - three were replicated four times each, with the remainder of the farm managed normally by the grower (treatment 4). Each replicate was a unit 5m long with six growing channels. Three units were spaced along each of four 18m long tables, with a 1m buffer between the units (total = 12 units) (Figure 17).

The entire trial was repeated using another four x 18m long tables, located 50m away from the first set to avoid predatory mite contamination. To meet the grower's marketing needs, four channels of cv. green oakleaf and 2 channels of cv. red oakleaf on one side were used. Treatments were applied to both varieties, but assessments were always conducted on the green oakleaf.

Figure 17: Hydroponic lettuce in a field situation with releases of *T. montdorensis* and *G. aculeifer*

T. montdorensis and *G. aculeifer* were introduced into the crop on the 2nd week after the seedlings were transplanted. *T. montdorensis* mites were released directly onto plants at a rate of 10 mites per plant and *G. aculeifer* were applied to the cocopeat mix (a layer of around 1cm) on the ground.

Three plants per unit were randomly chosen for the assessments. The number of WFT was counted on the day before the release of mites, then again one and two weeks after the release. Numbers of *T. montdorensis* on the lettuces were also counted one and two weeks after release. The presence or absence of *G. aculeifer* was checked by examining samples of the mix under a light microscope after the final week of the trial.

At each assessment time, WFT populations were also counted on lettuces managed in accordance with normal farm practices.

Cultural Practices

Impact of diseased plants on the spread of TSWV

Introduction

Western flower thrips are the main vector of tomato spotted wilt virus (TSWV). Once a plant is infected with TSWV it cannot be cured and the plant will sicken and die. Removing diseased plants from within crop or, preferably, from the site entirely, is an important part of farm hygiene that limits the spread of TSWV and the yield losses that are associated with the disease.

However, finding and removing diseased plants requires time and attention. As a result, diseased plants, crop residues and host weeds can be left in and around the crop. The pathogen can then be easily transported into the crop by vectors such as WFT, where it infects healthy plants.

The aim of this study was to determine how TSWV spreads from an infected plant into the remainder of a hydroponic lettuce crop. The rate of spread of TSWV through a hydroponic lettuce crop when vectored by WFT could then be determined.

Method

Trial 1

Lettuce seedlings were ordered from a known supplier with the request that no chemical applications were applied to the plants before the experiment. This allowed WFT to establish populations on the lettuces.

Two small greenhouses (approximately 25m^2) were set up with two benches of lettuce in each (total = 240 plants). The nutrient film technique (NFT) system was set up and ran at an ideal EC of 1.4-1.5 and pH of 6.0-7.0. Seedlings were visually checked for TSWV symptoms to ensure they provided a clean starting point for transmission tests. If there was any doubt about the status of a seedling, a TSWV test kit was used.

Lettuce plants with early TSWV symptoms were collected from collaborative lettuce growers in Richmond. Infection with TSWV was confirmed using Agdia TSWV test kits. Eight of these infected plants were transferred into the middle of each NFT system, as shown in the trial design (Figure 19).

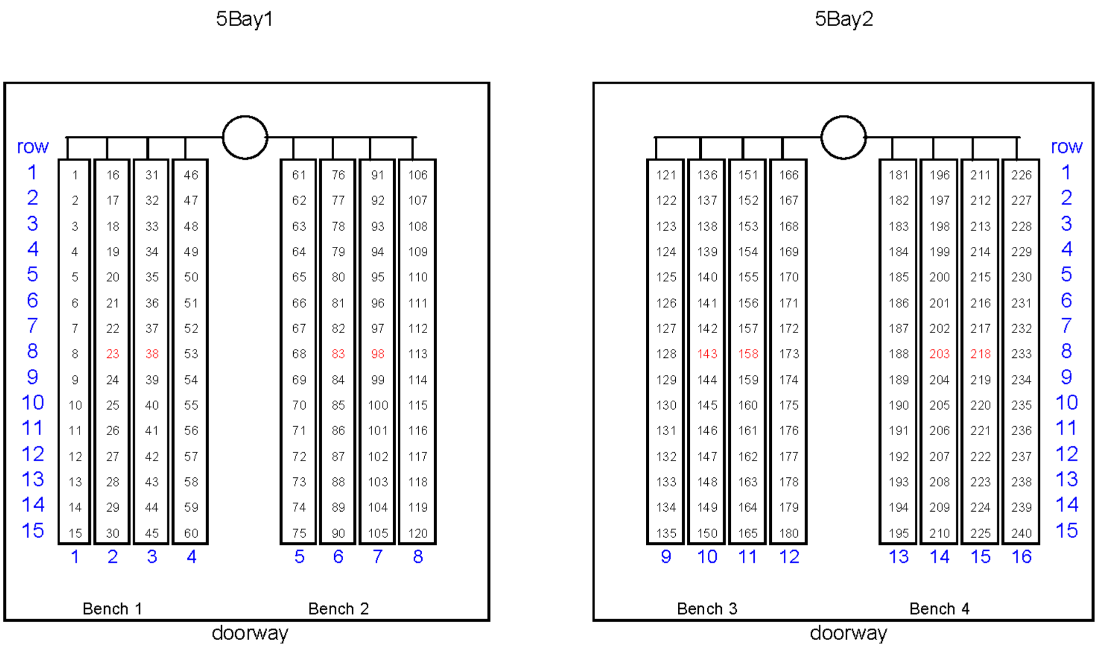


Figure 19: Experimental design of the TSWV spread trial. Two symptomatic plants were placed in the centre of each bench as indicated by numbers in red

Early stage WFT larvae were released directly onto the symptomatic plants with care being taken not to release onto the clean plants. This was to ensure that all the thrips surveyed within the greenhouse at later dates came from the diseased plants. Early life stages were used to ensure that the larvae spent enough time feeding on the diseased plants to acquire the virus.

The remaining plants in each greenhouse were checked for symptoms of TSWV every two days for four weeks. Plants with symptoms were checked using the Agdia TSWV test kit. The presence of thrips and/or their feeding damage was also recorded.

After four weeks, when lettuce were ready for harvest, the plants were removed a row at a time and placed into labelled bags. They were then thoroughly assessed in the laboratory for thrips, thrips feeding damage and TSWV infection.

Trial 2

Lettuce seedlings were ordered from a known supplier with the request that no chemical applications were applied to the plants before the experiment. This allowed WFT to establish populations on the lettuces.

One large greenhouse (approximately 300m^2) was set up with four rows of 52 cocopeat bags, irrigated by drippers (run to waste). Irrigation was set to the house using lettuce nutrient solution (EC 1.6, ideal pH 6.0-7.0) and bags were saturated before lettuce seedlings were transplanted.

One lettuce seedling was planted in each bag (total = 208 plants). Seedlings were checked for symptoms of TSWV before transplanting.

Lettuce plants with early TSWV symptoms were collected from collaborative lettuce growers in Richmond. Infection with TSWV was confirmed using Agdia TSWV test kits. Infected plants were transferred into the middle two bags of each row with three TSWV symptomatic plants/bag.

Early stage WFT larvae were released directly onto the symptomatic plants with care being taken not to release onto the clean plants, as previously described.

The remaining plants in each greenhouse were checked for presence of thrips and symptoms of TSWV every two days for four weeks. After four weeks, when lettuce were ready for harvest, the plants were removed a row at a time and placed into labelled bags. They were then thoroughly assessed in the laboratory for thrips, thrips feeding damage and TSWV infection.

Impact of “sticky ribbons” on the spread of thrips

Introduction

Preventing pests from entering and attacking a crop is another key component of an IPM strategy. Blue and yellow sticky tape/ribbon (aka ‘Rollertape’) are commercial products used to mass-trap flying insects. They are similar to blue and yellow sticky traps (used to monitor flying insects) but are supplied as a continuous roll. Large surfaces of sticky ribbon can be positioned in areas likely to experience heavy pest pressure, such as along ventilation windows, at the start of crop rows and/or directly above the crop.

This trial evaluated the effectiveness of blue and yellow sticky ribbon to trap WFT and reduce their numbers within the lettuce crop. Two different positions of the sticky ribbon were assessed in terms of the number of WFT that were captured as well as the resulting in-crop WFT population. Thrips were introduced by placing infested sowthistle weeds 2m away from the trial units of lettuce crop. This method had the advantage of also testing the speed and ability of WFT to move from surrounding weeds into a crop of hydroponic lettuce.

Methods

Pesticide-free lettuce seedlings were ordered from a known supplier as previously. Sowthistles (*Sonchus oleraceus*) were grown from seeds collected in the field. Sowthistle was used as it is common host of both WFT and TSWV.

Cocopeat bags were used as planting medium. The bags were saturated with lettuce nutrient solution (EC 1.6, ideal pH 6.0-7.0) before the seedlings were transplanted. Six sowthistles or two lettuces were planted into each cocopeat bag and arranged in the greenhouse as shown in the experimental design (Figure 22). Six bags of lettuce formed an experimental unit.

Star pickets were used at the corner of each unit to support the sticky ribbons (Figure 23). Treatments consisted of a control (no sticky ribbon), blue *or* yellow sticky ribbon positioned around each unit of lettuce (600mm above ground level) and blue *or* yellow sticky ribbon positioned around and above each unit of lettuce (800mm above ground level).

All plants were inspected at the start of the trial for symptoms of TSWV or thrips damage. WFT larvae were then released onto the sowthistles. The sticky ribbons and lettuces were examined for WFT weekly for five weeks. One lettuce was removed from each unit at each evaluation time. Any WFT present were rinsed off and counted under a compound microscope. Thrips on sticky ribbons were counted then circled with pen to prevent subsequent recounting.

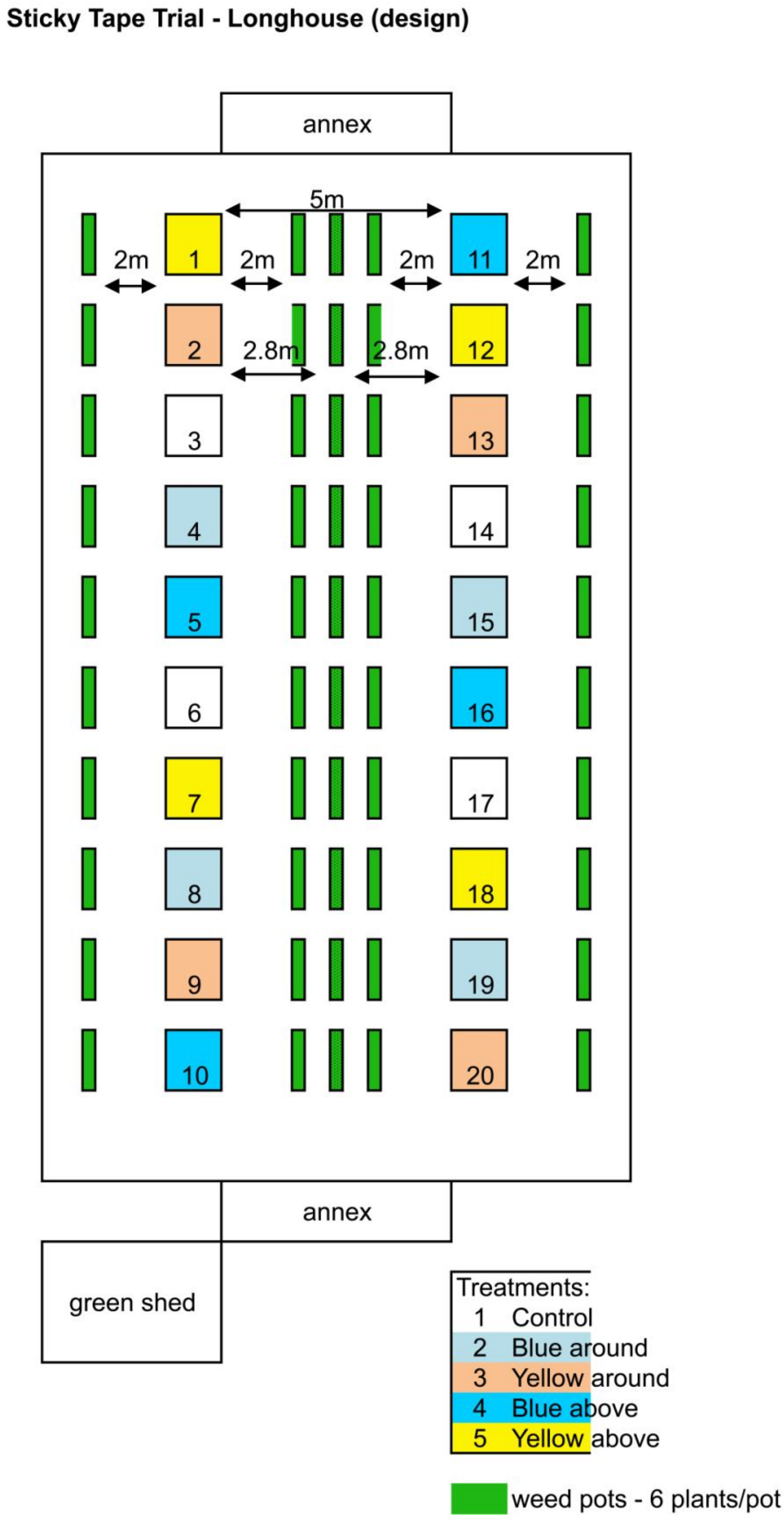


Figure 22: Experimental design for sticky ribbon trial with lettuce and sowthistle planted out in randomised blocks.

Figure 23: Sticky ribbon set up on a single unit. Ribbon was suspended from star pickets around the outside of the experimental unit. The unit was located 2m from sowthistles infested with WFT

Survey of alternate hosts to WFT and TSWV on lettuce farms

Introduction

A key component of an IPM strategy is to prevent pests and disease from entering and increasing in a crop. Hygiene practices, including rogueing (removing diseased plants from the crop) and the management of weeds within the crop and surrounding area could affect thrips numbers and disease incidence.

This trial focussed on identifying the level of pest and disease pressure experienced by lettuce growers in the Sydney Basin. A survey was conducted examining the presence or absence of alternate hosts to TSWV and WFT and what measures growers used to control these plants. The aim was to inform growers about alternate hosts and hygiene strategies that could prove beneficial.

Method

A literature review was conducted listing all the known TSWV and WFT hosts that might be found in the Sydney Basin. Growers were contacted and permission was gained to survey weeds on 21 hydroponic lettuce farms and their surrounding area. Growers were also surveyed about their farm hygiene practices. The list of known hosts was cross-referenced with the species found on the farms.

Spray Coverage Trial

Introduction

Pesticides are an important part of any integrated pest management system, including control of WFT. Chemical controls need to be applied efficiently, and in such a way as to maximise their effect against the target organism. This is particularly important in the control of organisms such as WFT, where sub-lethal doses due to incomplete crop coverage can rapidly give rise to a resistant population.

On commercial lettuce farms in the Sydney Basin, chemical sprays are mainly applied with tractor-driven blowers. However, there has been concern that coverage by this method is not good enough to effectively target WFT in hydroponic lettuce.

This trial tested the spray coverage achieved using different application methods, including the type of sprayer commonly used in commercial hydroponic lettuce farms. The method developed could by adapted by farmers to check the effectiveness of their own spraying method.

Methods

Four methods of pesticide application (Figure 27) were tested for their relative spray coverage in hydroponic lettuce crops:

1. tractor driven blower (current commercial practice)
2. personal knapsack sprayer
3. tractor driven boom sprayer
4. vehicle pack spray unit

Each spray method was tested on a different table of lettuce. Selected tables were separated from each other by at least two other tables to ensure drift did not affect the results.

Water sensitive paper strips (20mm × 100mm, Hardi Sprayer Co.) were placed in sample plants to test the spray coverage. Each sample lettuce was divided in half by height, designated upper and lower. The first two strips were positioned at the upper and lower levels of the plant and to the middle of the growing channel so as to be closest to the sprayer. Two additional paper strips were spaced evenly on leaves around the plant on each level (total = 6 strips / lettuce) (Figure 28). A pin was used to secure each strip to the leaf.

For the test of the blower (Model: Silvan Tubo Miser, 40-60psi, operated at 1st gear), plants were sampled 1m, 3m, 5m and 7m from the beginning of each row. For the boom sprayer (model: Hardi Boom, capacity 666L, pressure at 120psi, 11 nozzles, operated at 2nd gear, speed at 5km/h), plants were sampled 1m, 2.5m, 4m and 5.5m from the beginning of each row. All applicators were calibrated as per their usual settings as used by the grower. Blowers and boom sprays were standard for their use across the crop.

Figure 27: Examples of the spray techniques being assessed in the trial. Clockwise from top left, the blower, knapsack, vehicle pack sprayer and the boom spray

Figure 28: Placement of water sensitive paper.

After the sprays were applied the paper strips were allowed to dry, then collected and placed in separate plastic bags according to location and spray type.

Each paper strip was then copied into transparency film so that only the blue spots showed on the film (the original buff colour copied as clear). A Li-Cor 1300 LAM area meter was used to measure the total area of blue on each film, expressed as mm^2.

Results

Reduced Risk Chemicals

Efficacy of HGW86 against Western flower thrips

Counts of adults and nymphs were pooled and all treatments significantly increased the mortality of WFT when compared to the negative (water) control (Figure 4). Spinosad, the industry standard, showed the greatest efficacy against WFT over the course of the experiment. However, WFT is known to quickly develop resistance against spinosad particularly when used as the sole mode of control, so it is unlikely that this level of control would persist over a long period of time (Herron *et* al., 1996).

The two rates of HGW86 were not significantly different, both causing significant mortality of WFT compared to the control. This suggests that the lower rate could be suitable for the control of thrips in hydroponic lettuce (Figure 4).

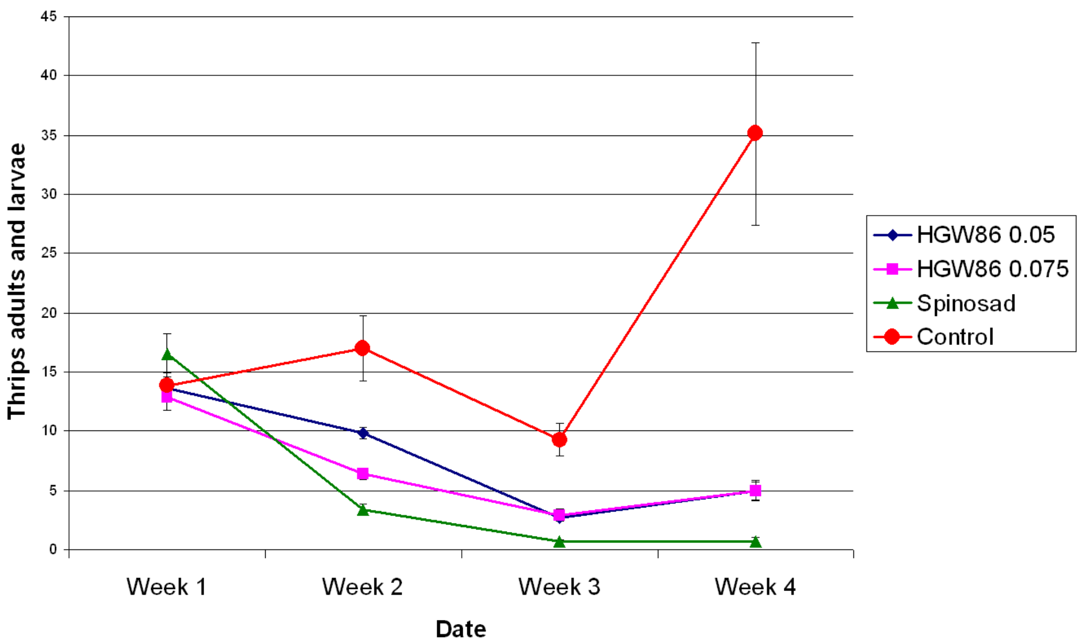


Figure 4: Efficacy of HGW86 against WFT populations on a hydroponic lettuce crop. Numbers are average adult and larvae per plant. Treatments were repeated weekly.

IPM compatible pesticides are likely to be key components of any successful WFT management program. Thrips ability to develop pesticide resistance means that relying on one product alone will inevitably lead to pest management program failure. Giving growers access to a number of different pesticides with different modes of action that they can use in rotation with other strategies is essential for any long-term management of this pest.

The results suggest that HGW86 would be suitable to register for use on hydroponic lettuce against WFT. If the producer pursued registration for use in hydroponic crops it may be possible to complete registration in approximately 12 months. Alternatively, industry may pursue an emergency permit application for use outside of registration.

Compatibility of HGW86 with *Transeius montdorensis*

HGW86 did not cause any significant biological effects on *T. montdorensis* (Figure 6). For the duration of the experiment there were no reductions in successful egg hatch and no increase in mortality for any rate. There were some minor numerical increases but these were not statistically significant.

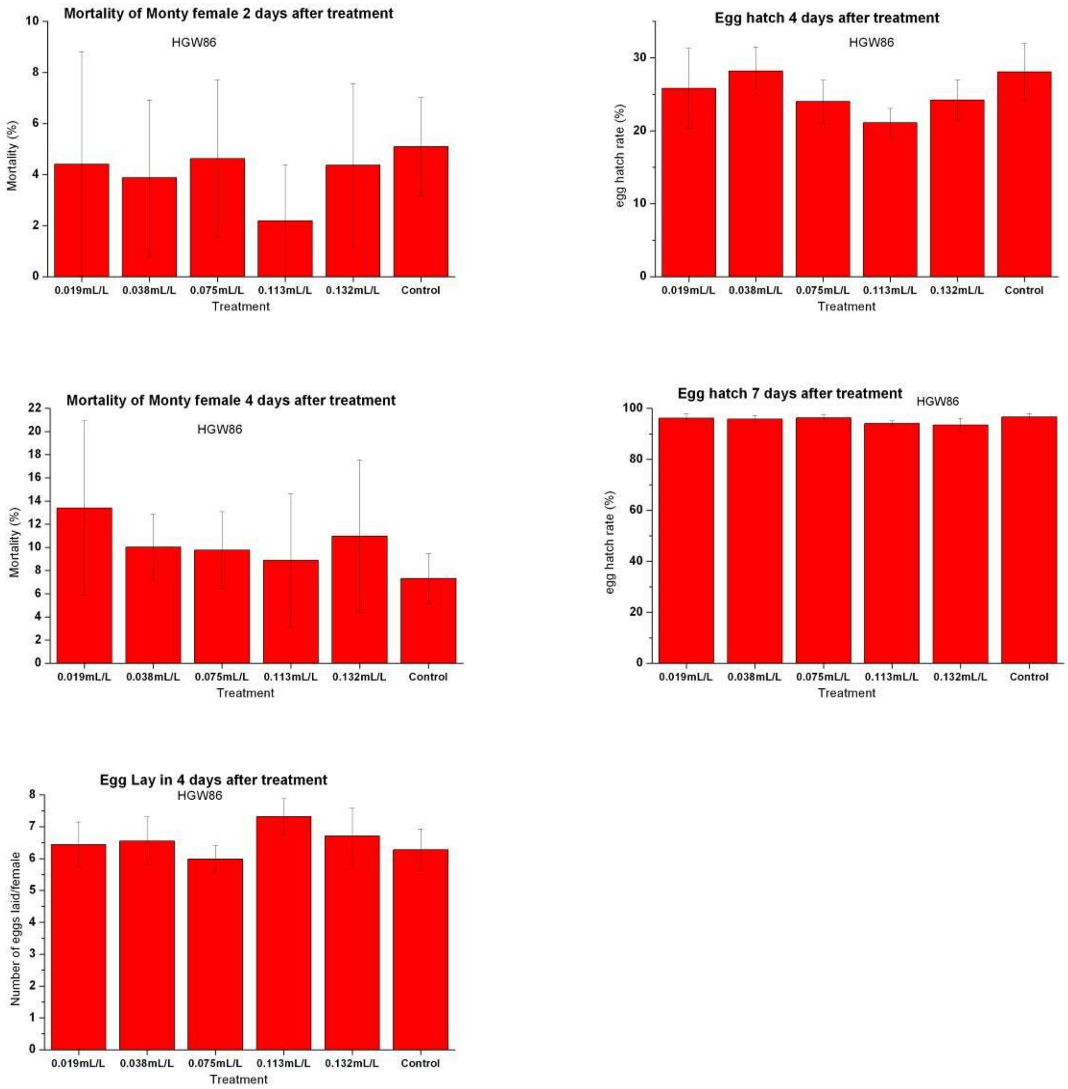


Figure 6: Effects of HGW86 on *T. montdorensis.* None of the treatments increased mortality or affected secondary biological factors

HGW86 is not currently registered for use on hydroponic lettuce. However, DuPont has been discussing the possibility of applying for registration of this product in several production systems based on the data that was developed in this project. If registration is pursued the additional data they would need to collect (possibly including off target effects, residues, persistence and so on) may take approximately 12 months. Whilst primarily targeting greenhouse whitefly, HGW86 has proven to also be effective against WFT. This trial provides evidence that there are no non-target effects when applied in production systems also using *T. montdorensis*. The product can therefore be considered to be compatible with IPM and the use of biological control agents.

Combining HGW86 with *Transieus montdorensis* for control of WFT in hydroponic lettuce

Pre-treatment counts confirmed that all treatment plants had similar numbers of WFT present before sprays were applied.

All treatments significantly reduced the numbers of WFT compared to the negative (water) control (Figure 7). The reduced risk pesticide, HGW86, provided significant pest reductions when used alone and in conjunction with *T. montdorensis* mites. This level of control continued for the duration of the trial.

The single release of *T. montdorensis* provided significant control for the duration of the trial, although the reduction in thrips numbers was not as great as that resulting from application of HGW86. Numbers of *T. montdorensis* recovered from the lettuce plants declined after 3 weeks. This suggests that, while the predatory mite provided a good pest management option, it did not establish within the lettuce crop. This suggests that *T. montdorensis* is best used as an inundative biological control; re-applications of the mite would be needed to maintain control in the long-term.

This trial has demonstrated that HGW86 and *T. montdorensis* can control WFT in hydroponic lettuce crops within a greenhouse environment. Using both techniques in combination provided the best control. While this method proved effective in the greenhouse environment, testing in a field, or covered, crop situation would confirm its effectiveness under more commercial conditions.

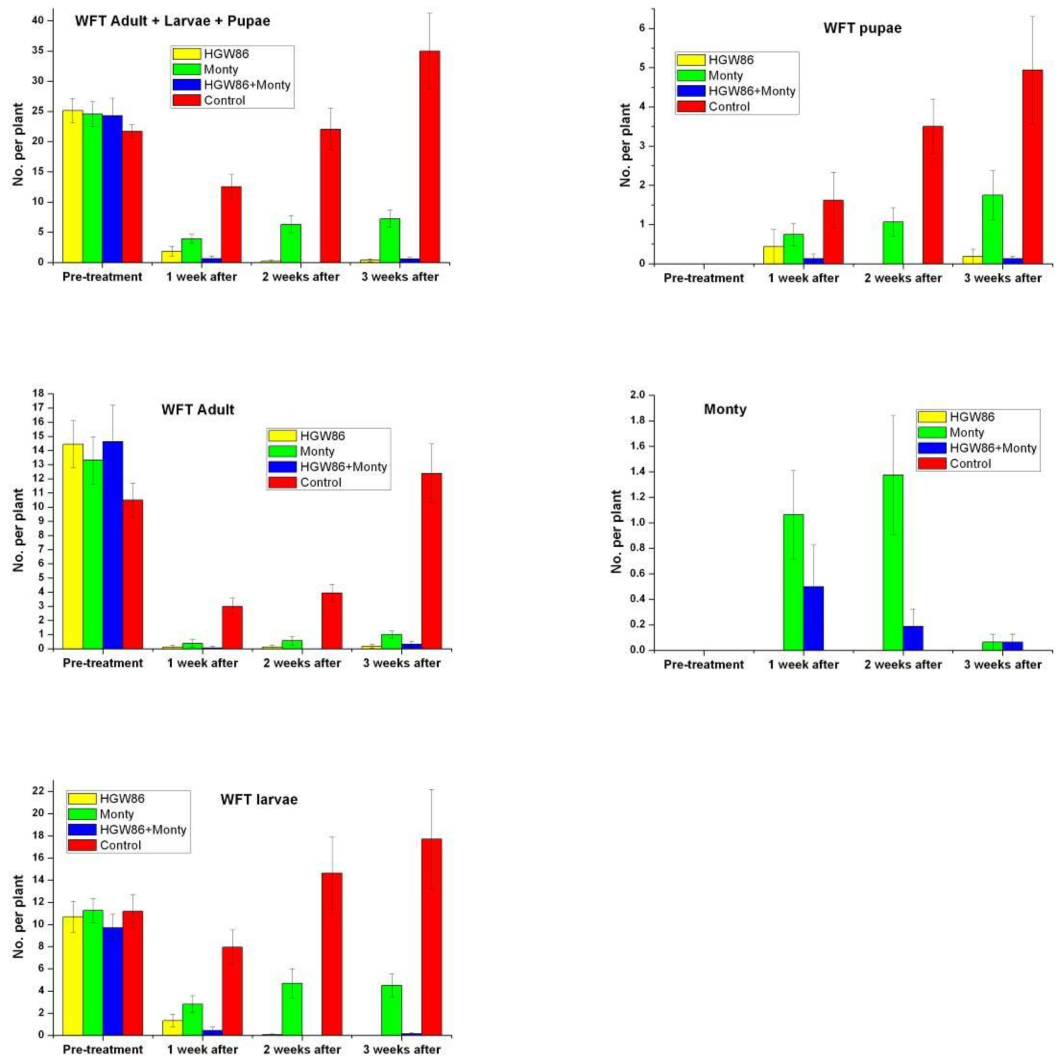


Figure 7: Effects of HGW86 and *T. montdorensis*, alone and in combination, on WFT populations. All treatments significantly reduced WFT numbers compared to the control

Compatibility of Agri50NF with *Transeius montdorensis*

Results show that Agri50NF can cause minor mortality of female *T. montdorensis* adults when used at the standard rate (3.0 ml.L^{-1}) or higher (Figure 5). This increase in mortality was only marginally statistically significant, and numerically not great. The impact on *T. montdorensis* populations would be minor. There were no other significant effects on biological measurements.

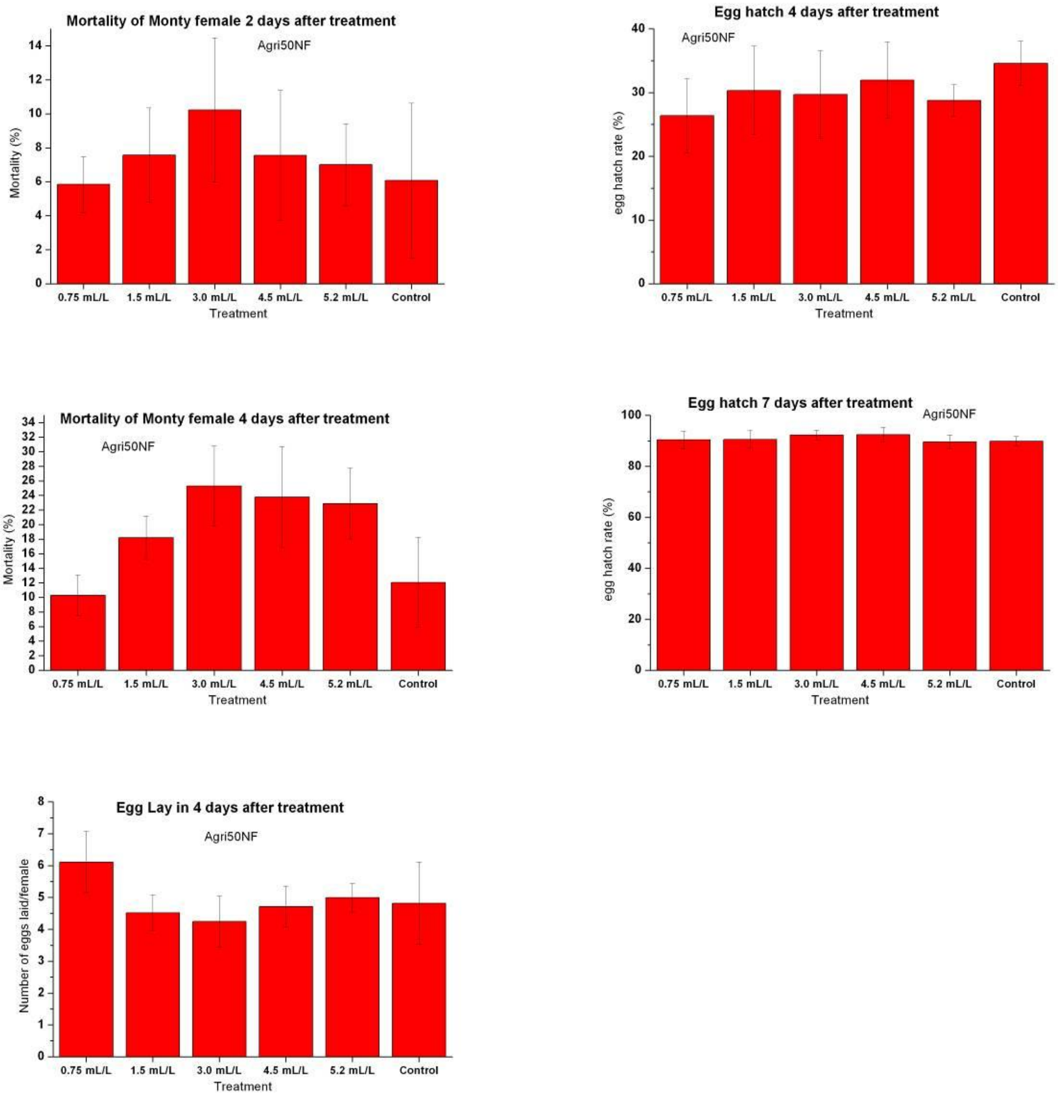


Figure 5: Effects of Agri50NF on *T. montdorensis* in laboratory bioassays. Higher rates slightly increased mortality but did not affect secondary biological factors

This trial indicates that Agri50NF does not have a commercially significant effect on *T. montdorensis* survival, egg lay or egg hatch. Agri50NF has been shown to have excellent efficacy against WFT in a cropping situation. If this pesticide was registered for application in hydroponic lettuce production systems, it would be considered compatible to use with *T. montdorensis* as part of an IPM program.

Compatibility of Biocover with *Transeius montdorensis*

Whilst Biocover caused significant mortality of *T. montdorensis* after four days (Figure 8), the difference (approx 12% increase) was not great enough to be commercially significant were this product being used in an IPM system. Similarly, the differences seen in egg lay and egg hatch across the extent of the trial are, whilst statistically significant, numerically small.

The results suggest that care should be taken when applying Biocover. It may be best to consider spot spraying this product, focussing on areas of high pest infestation. However, using the product according to the label in areas where *T. montdorensis* is active should not greatly limit the establishment or effectiveness of the mite.

Based on these findings it would be appropriate to list Biocover as an IPM compatible product. The product is suitable for use in production systems that are using biological control agents.

Biocover is considered a greater commercial reality than the other pesticides tested and work is continuing with the producer. Registration in hydroponic lettuce crops, if pursued by the registrant of the product, would potentially be complete within 12 months.

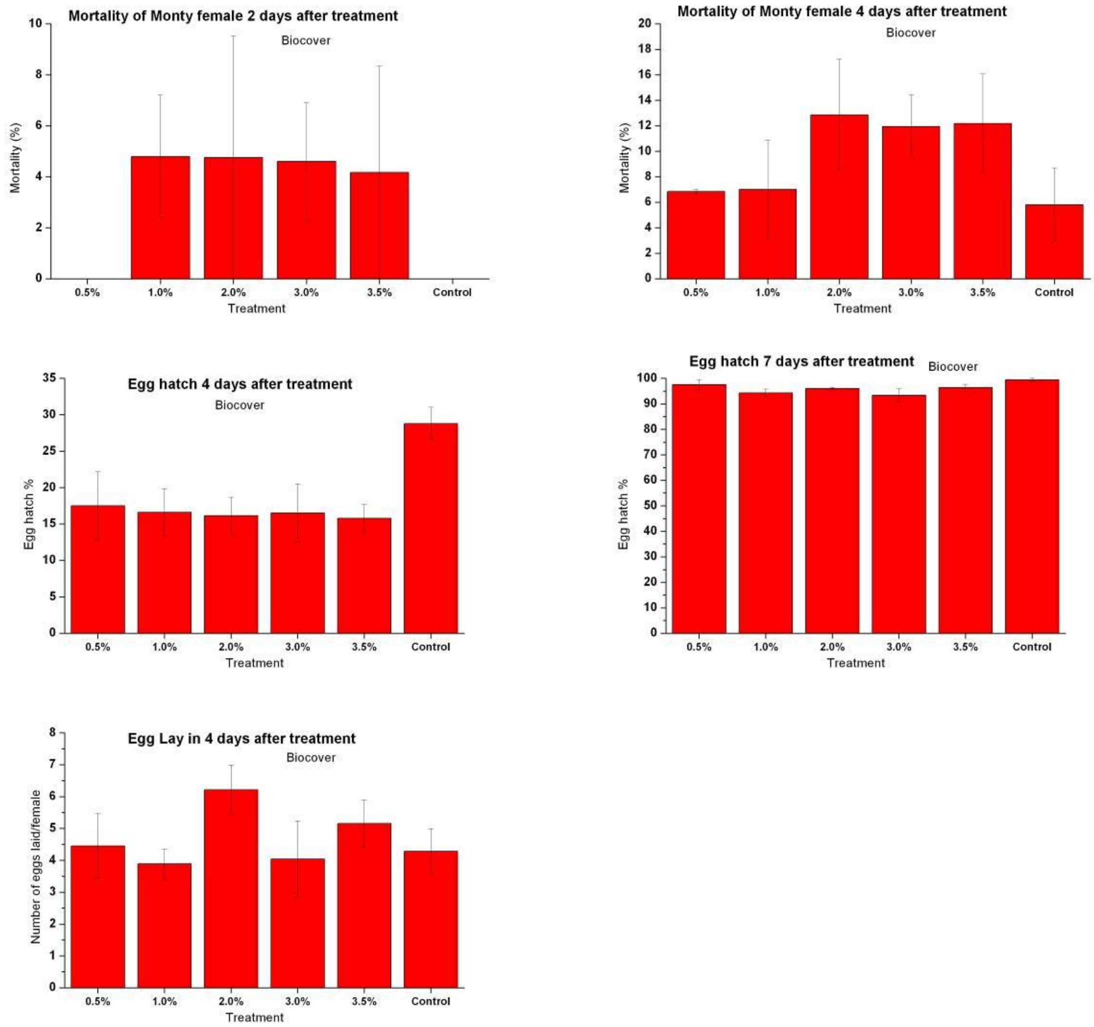


Figure 8: Effects of Biocover on *T. montdorensis*. Although there are some minor statistical differences the numerical effect was not great

Biological Control Agents

Control of western flower thrips by *Geolaelaps aculeifer* released under the crop

Results and Discussion

Introducing the soil dwelling predatory mite *G. aculeifer* significantly reduced the number of WFT adults on the lettuce plants for the duration of the trial (Figure 10). Treatment with *G. aculeifer* also significantly reduced the numbers of WFT larvae in the first three weeks of the trial although the reduction was numerically very small. By the final week of the trial this effect was no longer significant although numerically the difference was larger. This may reflect the reduced numbers of predators present by the end of the trial. Due to the soil dwelling nature of this predator, it was expected that pupae numbers would be reduced and it would follow that adult numbers would also decline. If the trial was able to continue for a longer period of time there may be a greater effect on larvae numbers on the plant.

While the reduction in numbers of pupae was promising, the effect on adult populations of WFT in this trial was numerically small. It is possible that greater control could have been achieved with additional releases of the predatory mite. It is also possible that combining this management strategy with another tool such as a compatible pesticide application or another biological control agent would have enhanced the ability of *G. aculeifer* to control WFT. Subsequent trials were planned to test a management system that was more representative of a lettuce growing system commonly found in the industry. This results of this trial are presented in the following section - Control of western flower thrips by *Geolaelaps aculeifer* released on the ground.

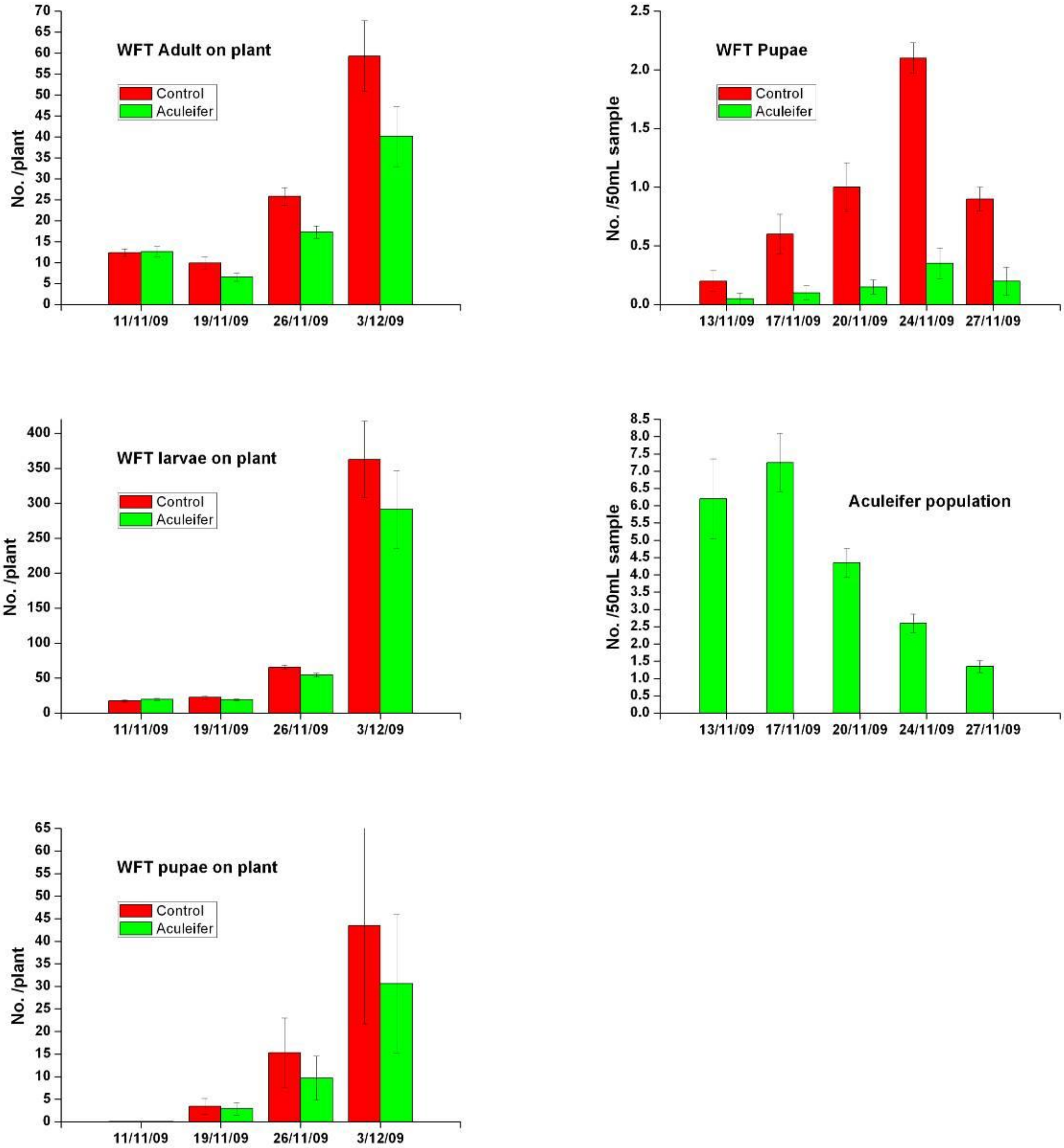


Figure 10: Numbers of thrips per plant and *G. aculeifer* in trials with the predatory mite distributed in under bench media to attack WFT pupae

Control of western flower thrips by *Geolaelaps aculeifer* released on the ground

As in the previous trial, introducing the soil dwelling predatory mite *G. aculeifer* significantly reduced the number of WFT adults on the lettuce plants, particularly by the end of the trial when predation on pupae would have had more of an effect. While the effect on adults was numerically small, reductions in numbers of pupae in the cocopeat media were highly significant (Figure 12).

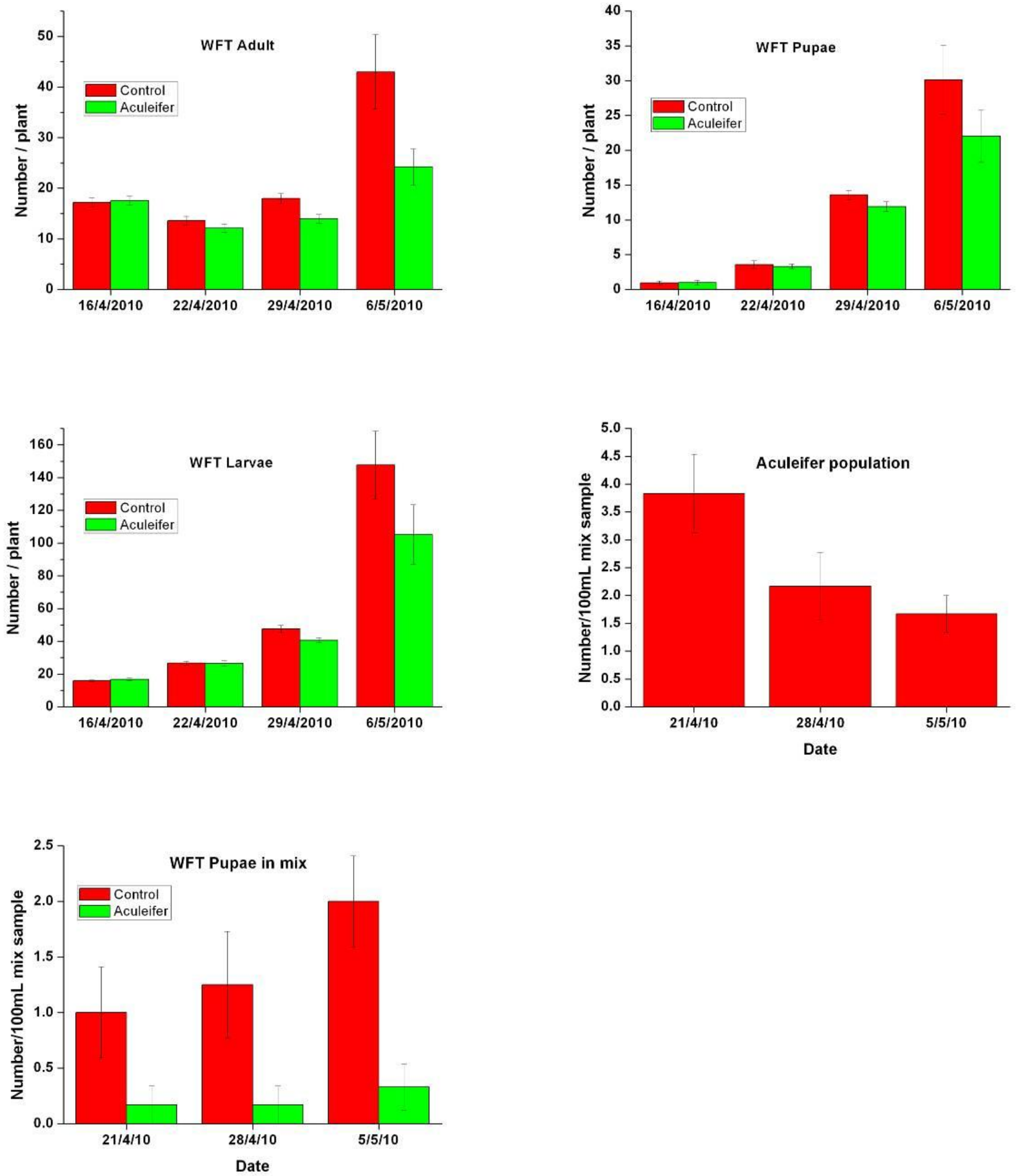


Figure 12: Effect of introducing *G. aculeifer* to the ground substrate to manage numbers of WFT in lettuce crops. WFT adults and pupae were significantly reduced compared to the controls.

As with the earlier trial, numbers of the predatory mite recovered from the media on the ground diminished over the course of the experiment. This could reflect the complex hunting environment for the predators. It is possible that the population of predatory mites would be more stable with increased pest pressure and, therefore, improved opportunities for predation.

For this management strategy to be effective, *G. aculeifer* predatory mites need to be used in conjunction with another biological control agent or compatible pesticide. The results also suggest that frequent releases of the mite are needed, as a single release is not sufficient to maintain effective control of adult WFT.

Control of western flower thrips by *Transieus montdorensis* in field lettuce conditions

As the number of released *T. montdorensis* per lettuce plant increased, the WFT population decreased. Population suppression was greatest two weeks after initial introduction of the predatory mites. After three weeks WFT populations started to increase, regardless of the number of mites originally released (Figure 14).

Distributing the mites to a single plant, every 2nd plant or every plant within the block had little effect on the ability of the mites to control the WFT population. This demonstrates that *T. montdorensis* moves around the lettuce plants when searching for prey. While releasing the mites onto alternate plants was slightly better than the other methods, the results suggest that releasing the mites onto a single plant within a block of 7 distributed it widely enough for it to be an effective predator. Compared to distributing mites to every plant, this greatly reduces the labour required.

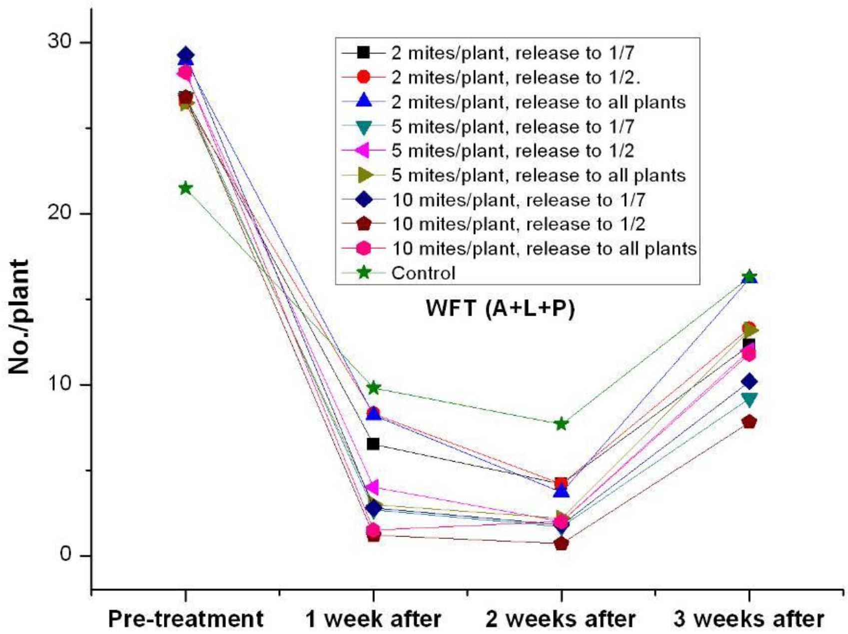


Figure 14: The effect of introducing 2, 5 or 10 predatory mites to 1 of 7 lettuces, every 2nd lettuce or every lettuce on populations of WFT. Mites significantly reduced WFT populations, especially when more were released per plant, distribution had less effect.

Numerical differences between the control and biological control treatments were at times quite high with WFT numbers reduced from approximately 10 per plant to only one or two. These effects are seen from applying a very low number of predatory mites and show a consistent and prolonged predation that has reduced numbers significantly.

Over time the number of WFT increases, though at a slower rate in treatments where the mite is applied. The effectiveness of this method could be improved by repeated releases or increasing the number of mites released. The number of predatory mites released was quite low compared to other systems with larger plants.

This trial indicates that *T. montdorensis* can reduce populations of WFT on hydroponic lettuces growing in an open environment. Further analysis is necessary to determine whether damage is reduced below economic threshold levels with this method alone. Combining releases of *T. montdorensis* with releases of *G. aculeifer* or compatible, reduced risk pesticides could provide better control of WFT populations.

Control of western flower thrips using *a* combination of *Transeius montdorensis* and *Geolaelaps aculeifer*

Populations of WFT adults, larvae and pupae were significantly reduced in the presence of the two predatory mite species compared to the untreated controls (Figure 15). Combining the two complementary predatory mites reduced WFT populations on the leaves by 80 – 90%.

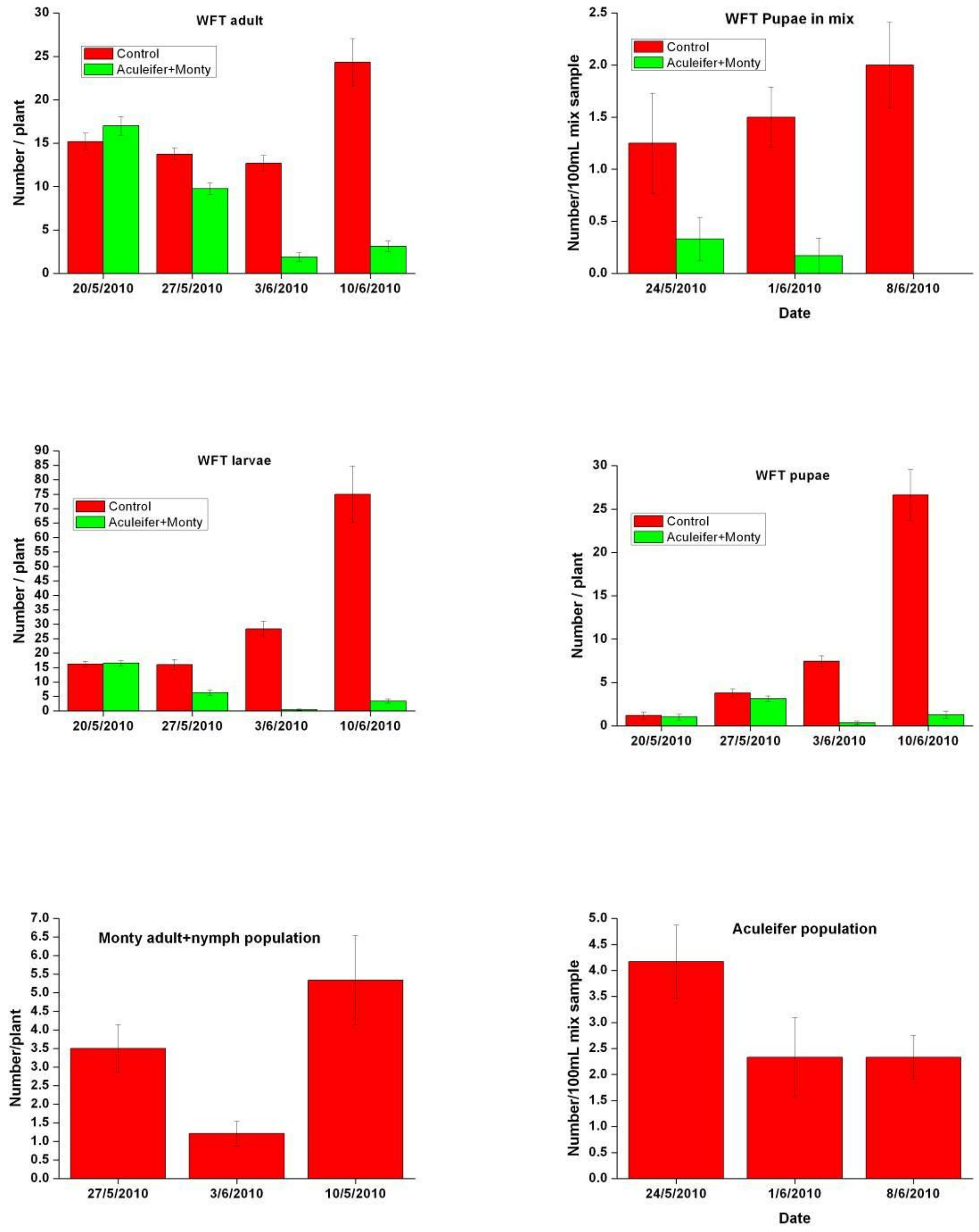


Figure 15: Effect of releasing both *T. montdorensis* and *G. aculeifer* on WFT populations on hydroponic lettuce in a greenhouse. The predatory mites significantly reduced all lifestages of WFT

In this trial the biological control agents were released only once, albeit into conditions that were highly suitable to both of the mite species used. The results suggest that repeated releases could provide consistent, season long management of WFT in commercial greenhouse crops. Releases may be less effective if environmental conditions are not favourable to the mites. However, even under these conditions, regular and thorough monitoring of pest and predator populations should make control possible. If predatory mite numbers cannot be maintained at high enough levels to provide commercial control, complementary reduced risk pesticides could be used to improve the reliability and effectiveness of this method.

Control of western flower thrips by *a* combination of *Transeius montdorensis* and *Geolaelaps aculeifer* – *G. aculeifer* applied to lettuce plants

As found previously, populations of WFT adults, larvae and pupae were significantly reduced in the presence of the two predatory mite species compared to the untreated controls (Figure 16).

Although *G. aculeifer* is predominantly a predator in soil, it appears that its effectiveness is not limited by releasing it on the leaves, in conjunction with *T. montdorensis,* rather than the soil. This would mean that the ground area does not need any preparation and that releases may be done at the same time as *T. montdorensis*. The rates of *G. aculeifer were* also significantly reduced from ground trials presenting a considerable cost saving in this management practice. This provides efficiency in application that will make it easier for growers to utilise the predator.

The biological control agent *G. aculeifer* is commercially available to lettuce growers to manage thrips within their crops. These results suggest that it can be released either onto the leaf or into a media on the ground, making it easy to manage. Combining this predator with *T. montdorensis* can provide a high level of control of WFT in a greenhouse environment.

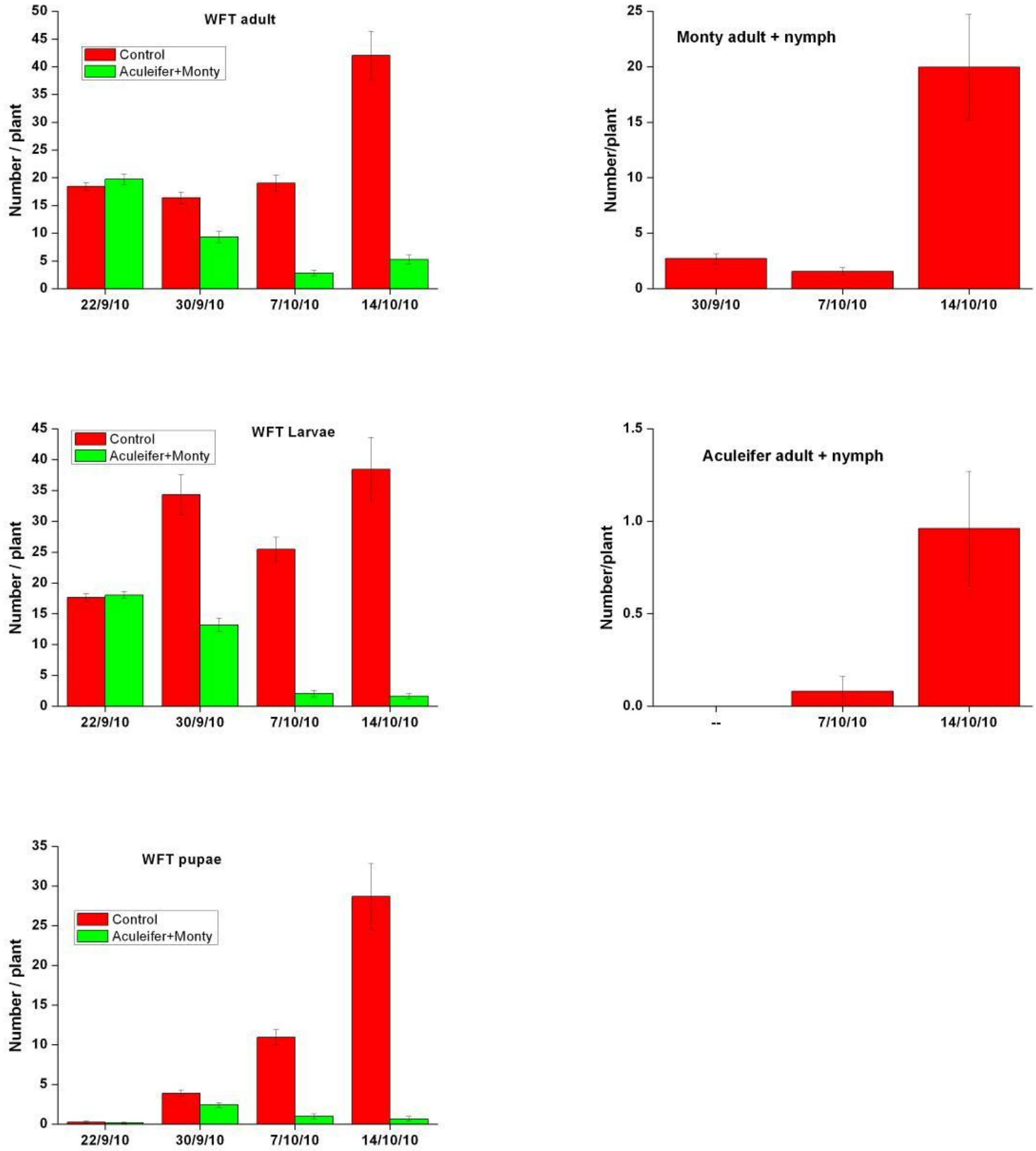


Figure 16: The number of WFT adults, larvae and pupae were all significantly reduced when *G. aculeifer* was released to the base of the plant along with *T. montdorensis*

Control of western flower thrips by *Transeius montdorensis* and *Geolaelaps aculeifer* in a commercial lettuce farm

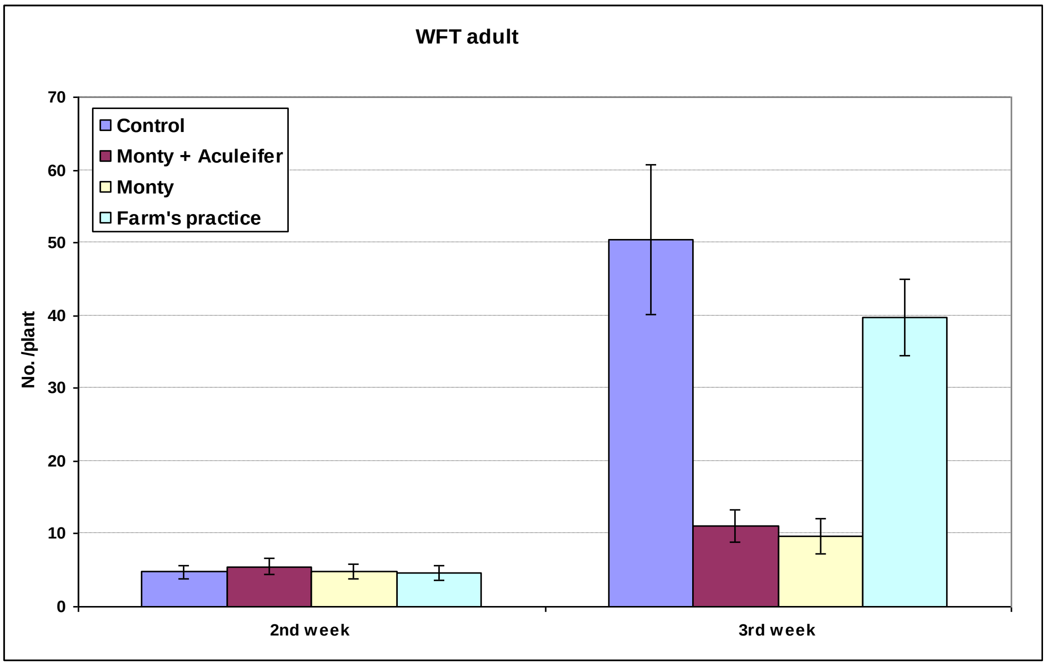
Pre treatment counts of the WFT population indicated that the pest was already spread evenly across the crop. The number of WFT active in the crop increased greatly during the third week of the trial. Measurements of the different replicates confirmed that this movement of WFT into the crop was uniform across the treatments.

Introducing *T. montdorensis* and *G. aculeifer* into the hydroponic lettuce crop significantly reduced the WFT population (Figure 18). The reduction in adult WFT was significantly greater than that achieved with management using conventional insecticides.

It is possible that the improved control under biological controls was because the predatory mites were already in situ when adult WFT arrived from other areas. It is also possible that pesticide applications were delayed or pesticides were used to which the local adult WFT population was already resistant.

While the predatory mites also significantly reduced the number of WFT larvae on lettuce plants, conventional insecticides provided a similar level of control on larval populations.

External factors such as temperature and humidity affect biological control agents to a greater degree than they affect conventional pesticides. While the predatory mites proved effective in a greenhouse, it had been thought that they may be less able to control WFT in the relatively harsh outdoor environment. Nevertheless, this trial demonstrates that *T. montdorensis* and *G. aculeifer* predatory mites can equal or exceed conventional pesticides when used to control WFT in commercial hydroponic lettuce crop.



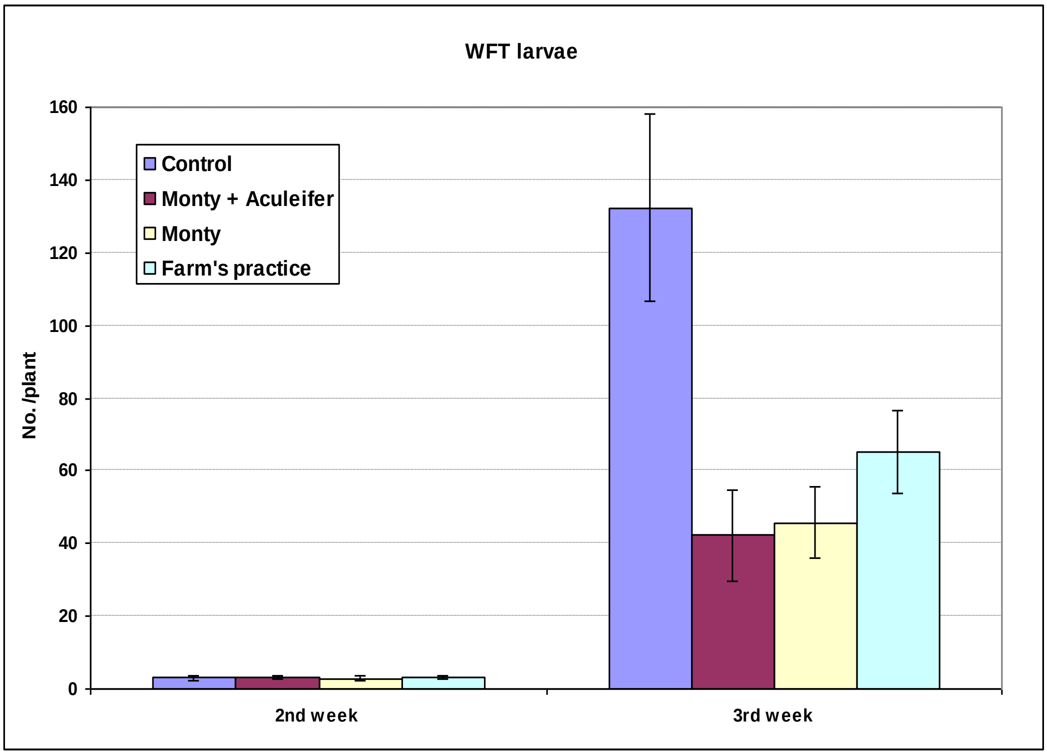


Figure 18: Populations of WFT adults and larvae on hydroponic lettuces after introduction of one or two predatory mite species, conventional chemical control or no treatment. Predatory mites significantly reduced WFT populations

Cultural Practices

Impact of diseased plants on the spread of TSWV

Trial 1

Western flower thrips were found only on the inoculated plants in the centre of each bench for the first 8 days of sampling. This was expected, as WFT larvae are wingless and cannot move easily between plants.

Once the thrips larvae pupated and emerged as winged adults they spread rapidly throughout the greenhouse. While WFT dispersed through the entire crop, the greatest concentration remained around the initial release sites (Figure 20). Thrips numbers were not assessed until the final count when a destructive sample was taken. The numbers shown (Figure 20) represent the entire row, not just that channel.

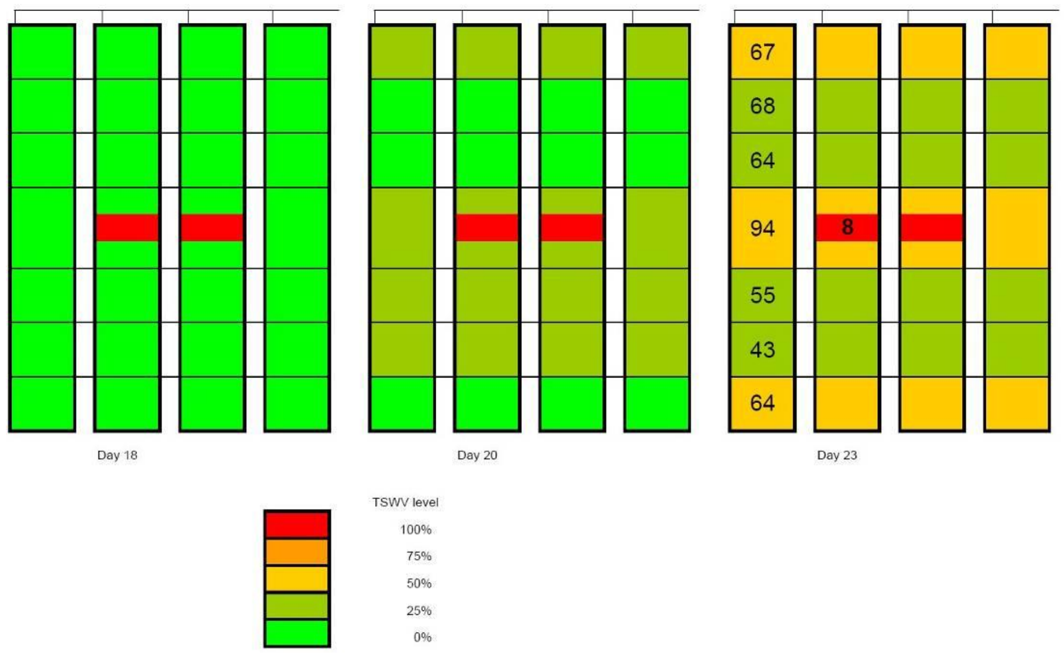


Figure 20: Tomato spotted wilt virus distribution at day 18, 20 and 23. Adult and larva thrips numbers are indicated for that entire sector of crop, each sector being two rows of plants. Numbers are only given in the final assessment after the diagnostic test was completed.

No symptoms of TSWV were observed in the crop for the first 20 days of the trial, apart from the previously infected lettuce plants. However, symptoms then began to appear on surrounding plants. Within three days the virus had spread to all parts of the greenhouse. Infection was confirmed using TSWV test strips. Symptoms were most severe close to the original release point, consistent with the movement of thrips outward from this location. By the end of the trial 29% of all plants were infected with TSWV.

Trial 2

As in trial 1, once symptoms of TSWV appeared in originally uninfected lettuce plants, the disease spread rapidly, radiating out from the original infection in the centre of the greenhouse (Figure 21). Disease severity and distribution increased daily, until 56% of plants were showing symptoms of TSWV.

The pattern of disease spread from the original infective plants was more pronounced than in trial 1. This was possibly due to the greater number of plants in each row and their location close to the ground: adults emerging from pupae on the ground had a shorter distance to fly to a host plant (15cm instead of 1m). Under these conditions they could be likely to fly directly to the nearest lettuce, rather than searching more widely.

The rate of spread of TSWV from a single inoculation point has not been previously documented in the literature. This study presents the first evidence that new infections of TSWV within lettuce plants quickly become a disease reservoir, allowing symptoms to spread rapidly throughout a cropping system.

These trials have demonstrated that a modest introduction of diseased plants, along with the vectors needed to spread the virus, can result in a major disease problem. Removing plants that show TSWV symptoms can greatly reduce spread of this disease, increasing the number and value of marketable plants. This is not limited to the crop, but includes weeds and “pet plants” which can also act as reservoirs of disease. Knowing which weeds are potential hosts can help focus attention on control and, therefore, minimising pest and disease pressure on the crop.

Although maintaining a high level of crop inspection and hygiene may be time consuming, it can clearly have a major impact on reducing the incidence of TSWV in lettuce crops.

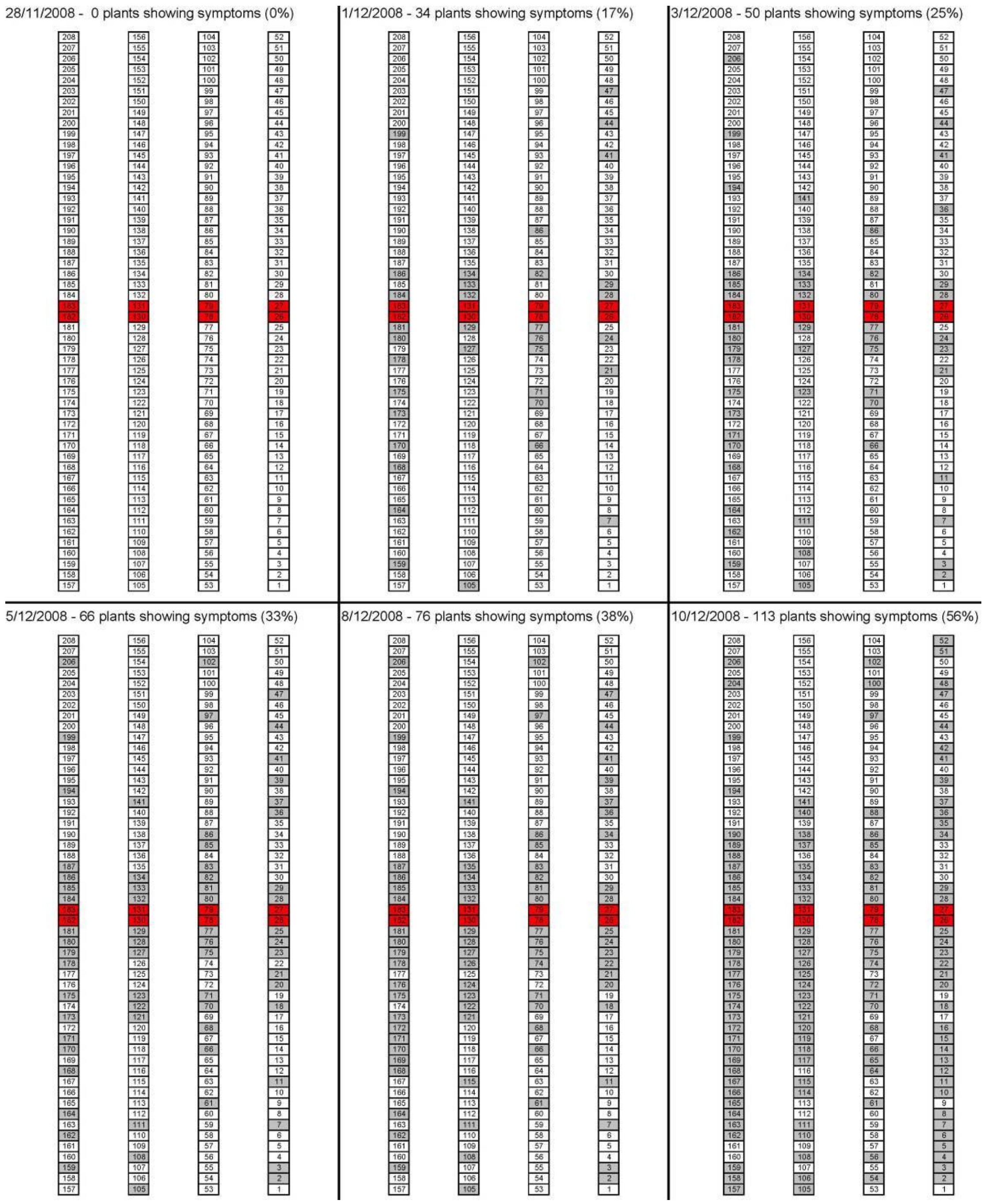


Figure 21: Tomato spotted wilt virus symptom development over time. Incidence radiated from the centre of each row where symptomatic plants were placed at the start of the experiment until 56% of all plants were showing symptoms

Impact of “sticky ribbons” on the spread of thrips

WFT numbers remained low for the first two weeks, so no differences were observed between the treatments until the third week of sampling. After three weeks, plants with yellow or blue sticky ribbon located low around the plant had fewer WFT on them than the untreated controls (Figure 24). Although this difference was not significant in week four, by the final week WFT populations were approximately 50% less on lettuces which had either blue or yellow sticky ribbon located around the unit or yellow sticky ribbon just above the crop canopy.

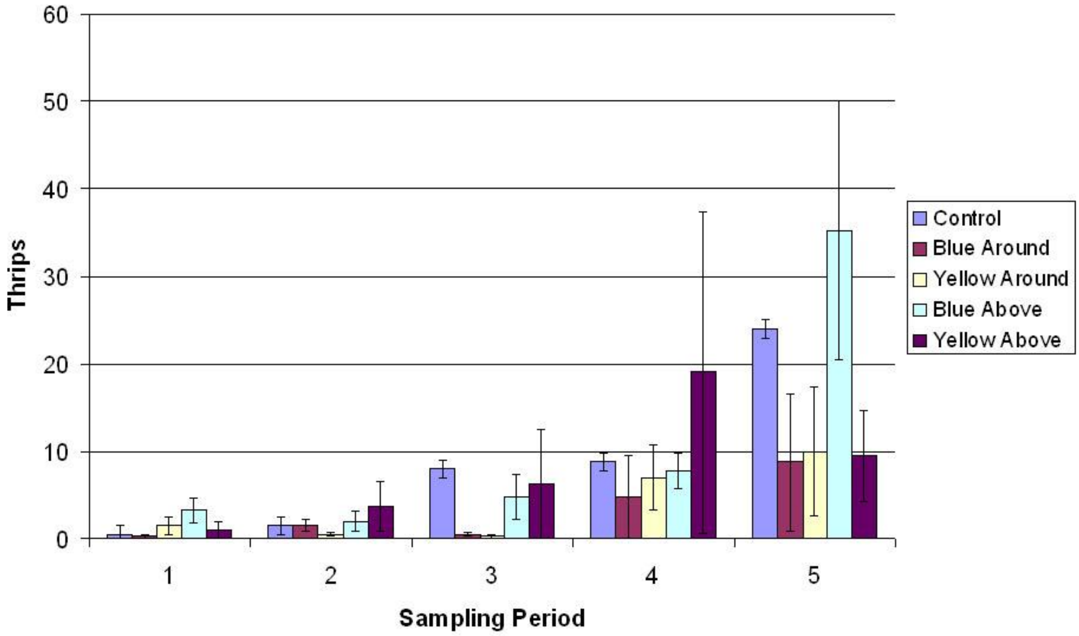


Figure 24: WFT populations on lettuce plants surrounded by yellow or blue sticky ribbon located above or around the lettuces, recorded weekly for five weeks

This result was confirmed by examining the number of WFT caught directly on each trap type. Yellow sticky ribbon consistently caught significantly more thrips than blue sticky ribbon, regardless of trap height (Figure 25). This reflects the number of WFT intercepted on their way into the crop. Whilst numbers were generally quite low, they clearly indicate that WFT is more strongly attracted to yellow than blue.

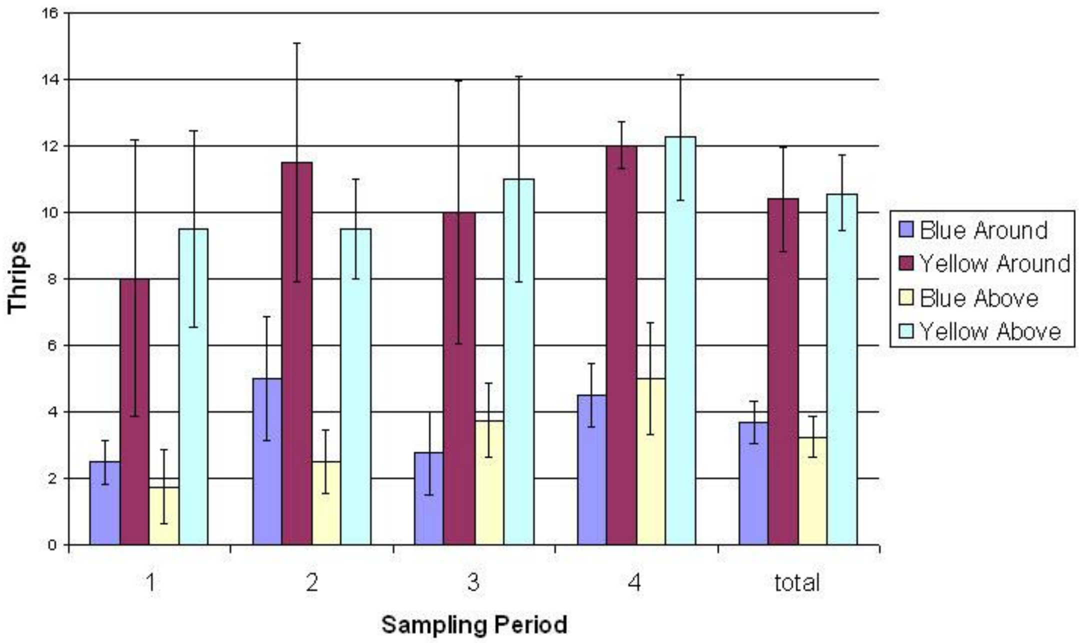


Figure 25: WFT counts on the outside of yellow or blue sticky ribbon located above or around units of lettuces, recorded weekly for five weeks. Yellow sticky ribbon consistently intercepted more thrips than blue.

Once WFT reached the lettuces, trap colour became less important (Figure 26). Trap catches were also lower on the inside than on the outside of the sticky traps. This may indicate that, once WFT have arrived at a suitable host, they will not necessarily travel further. While earlier evidence demonstrated that thrips move from plant to plant, long distance movements are less likely where food is not limited and population pressure is low.

This result suggests that there is a potential to use sticky ribbon around the perimeter of hydroponic lettuce crops to reduce incursions by WFT. The experimental units used in this trial, however, were quite small. Circling benches with sticky ribbons would be quite difficult to set up, create harvesting issues and possibly be less effective than the method used in this trial.

The greater attraction of WFT to yellow sticky ribbon over blue, however, suggests that this material could be used strategically in specific areas of protected production systems. Greenhouse growers may achieve some good results by locating large areas of yellow sticky traps or ribbon at doorways, entries, vents or known points of ingress for thrips. The highly attractive trap may intercept the adults as they move into the crop and significantly reduce numbers. While this method is unlikely to be effective used alone, it could be combined with other strategies to improve overall control. The combination of strategies might include those detailed in earlier sections such as maintaining high hygiene standards, monitoring and early management of pest populations, plant breeding and the use of exclusion netting.

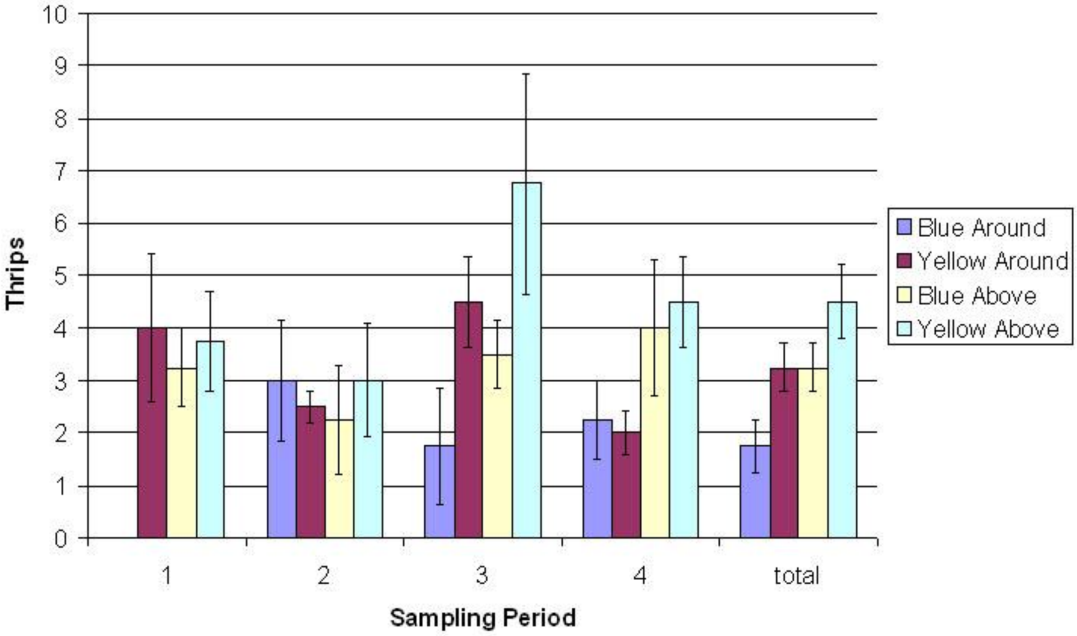


Figure 26: WFT counts on the inside of yellow or blue sticky ribbon located above or around units of lettuces, recorded weekly for five weeks. The lack of significant differences and low numbers suggests WFT travel only short distances once established within the crop

Survey of alternate hosts to WFT and TSWV on lettuce farms

There were 30 species of weeds that were identified as being a host for either TSWV or WFT. Of the 30 species, 12 were hosts for both TSWV and WFT. These present the greatest danger for hydroponic lettuce growers and were identified as a priority for removing from within the crop and around the farm.

The three most common weeds found that were found that were also potential hosts of WFT and TSWV were[1]:

1. Pigweed, *Portulaca oleraceae*, found on 14 farms
2. Mallows, *Malva* spp. found on 10 farms
3. Sowthistle, *Sonchus oleraceus*, found on 9 farms

Whilst many weed species can act as infective reservoirs of WFT and TSWV, control of these three species is the highest priority.

The highest priority weeds for hygiene maintenance were identified due to their status as hosts for both WFT and TSWV. These weeds include Amaranth (*Amaranthus* spp.), Capeweed (*Arctotheca calendula*), lamb's tongue (*Plantago lanceolata*), mallows (*Malva* spp.), nightshades (*Solanum* spp.), pigweed (*P. oleraceae*), purpletop (*Verbena bonariensis*), scotch thistle (*Onopordum acanthium*), sedge grass (*Cyperus esculentus*), shepherd's purse (*Capsella bursa-pastoris*), sowthistle (*S. oleraceus*) and wireweed (*Polygonum aviculare*). These weeds should be identified early on all properties and controlled to prevent the movement of either the pest or the pathogen.

On average, the hydroponic lettuce farms surveyed had >5 weed species that were hosts of TSWV or WFT growing close to the cropping area. Further, the farms had an average of 2 weed species that were hosts for both TSWV and WFT. Farms varied considerably in this regard. The worst performing farm in terms of weed control had 15 species of host weeds on the property, including four hosts for both the pathogen and the vector. In contrast, one grower had only a single weed host species on the farm, that being a grass nominally a host but a low priority for control.

Weed control and crop hygiene practices varied greatly between the surveyed growers. One grower maintained excellent hygiene, monitoring regularly for pests and disease and removing any diseased material. Another grower simply planted the crop and performed minimal activities until harvest time. It would be useful to compare the pest and disease levels at these two contrasting farms; this could provide some indication of the cost effectiveness of maintaining a high level of farm hygiene.

Grower action on finding a diseased plant also varied considerably. Six of the 21 surveyed growers bagged and disposed of plants immediately if they noticed any symptoms of disease. A further eight growers removed diseased plants but either left them on the property or collected them several days to a week later. This

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[1] Images courtesy of http://www.wswa.org.au, http://www.sbs.utexas.edu, and http://www.commanster.eu respectively.

effectively left the source of infection within the crop so is not an ideal practice. The remaining seven growers either did not monitor for diseased plants or took no action when they were found.

It was encouraging that many growers were already aware of the importance of removing diseased plants from the crop. However, the link between the spread of TSWV and the presence of weeds around the crop edge may be less clear. Workshops providing training in weed identification and management would assist growers in reducing pest and disease pressure and, therefore, adopting IPM practices.

Spray Coverage Trial

The boom spray and the vehicle pack gave the best coverage of the upper half of the lettuces. Both of these methods covered nearly 100% of the lettuces across the entire length of the channel (Figure 29). The knapsack sprayer gave slightly poorer coverage, with 80-95% coverage on top of the crop. The effectiveness of the blower declined significantly as the distance between it and the lettuces increased. At a distance of 7m, coverage was less than 20%, while coverage of even the closest lettuces was less than 80% (Figure 29).

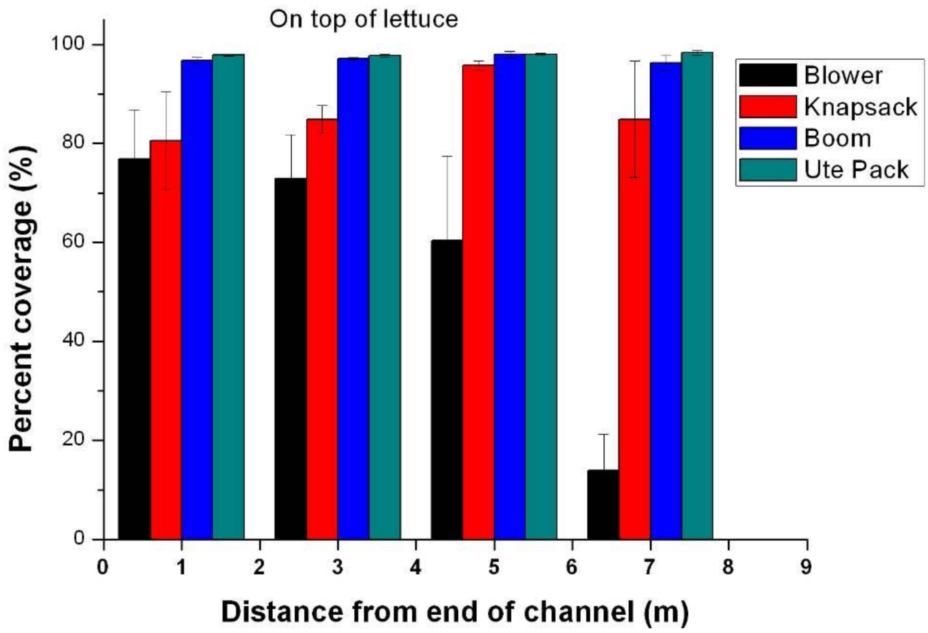

Figure 29: Spray coverage on upper half of lettuce from different spray equipment. Coverage is presented in relation to the distance from the applicator end of the channel.

The best coverage on the lower half of the lettuce plant was achieved using the vehicle pack sprayer. This method provided close to 100% coverage, even at the maximum distance from the equipment (Figure 30). The knapsack and boom sprayers were slightly less effective with 70-80% coverage. Once again, the blower was the least effective method tested, with only 35% coverage of the closest plants, declining to 20-30% 7m from the unit (Figure 30).

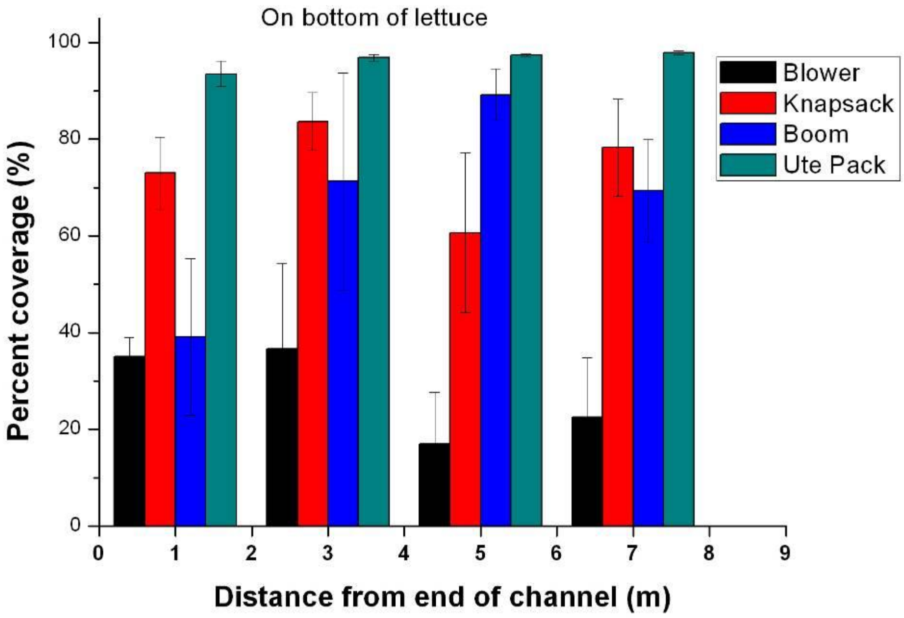

Figure 30: Spray coverage on lower half of lettuce from different spray equipment. Coverage is presented in relation to the distance from the applicator end of the channel.

Tractor driven blowers are fast and easy to use. However, in this trial, the blower did not provide good crop coverage. Incomplete coverage is likely to deliver sub-lethal doses to the pest. Not only does this mean that the original pest problem is not controlled, it increases the risk that insecticide resistance will develop. This method is therefore likely to cost more in the long term, especially if extra sprays are needed to overcome resistance.

Whilst boom sprayers may not be appropriate for all production systems, this method appears to offer a better balance between speed and effective coverage. The boom sprayer provided coverage close to that expected by spraying with hand and could give adequate control through the entire crop. If booms cannot be used – because of obstruction by roofing supports, for example - then a hand sprayer method such as a knapsack, vehicle pack or plumbed system would be most appropriate.

Discussion

Managing WFT in hydroponic lettuce offers many challenges to vegetable growers. Chemicals to control the pest are limited and pesticide resistance is a major and increasing issue. However, failure to control WFT can result in the rapid spread of TSWV through the crop, with catastrophic results.

This project has developed a number of tools that can be used by growers to control WFT integrated pest management system. Such systems are not necessarily intended to replace chemical controls, but can extend the usefulness of existing pesticides as well as providing additional options for pest control.

Key results from the project include;

Reduced risk pesticides

- The new pesticide HGW86 was found to be effective against WFT adults and larvae. However, it had little effect on the predatory mite *T. montdorensis*. Combining applications of this pesticide with releases of *T. montdorensis* provided a high level of control of WFT in the greenhouse.

- Two other reduced risk pesticides - Agri50NF and Biocover - were tested for compatibility with *T. montdorensis* and found to have minimal effects. These pesticides, if made commercially available and registered for use in these crops, could also be used as part of an IPM strategy.

Biological control agents

- The predatory mite *G. aculeifer* was assessed for its ability to control WFT when released in tubs or on the ground below hydroponic lettuce plants. The mite greatly reduced the number of WFT pupae, but had less effect on adults on the leaves.

- The predatory mite *T. montdorensis* was assessed for its ability to control WFT in an open field situation. Best results were achieved with 10 mites per plant. Releasing mites onto one lettuce in seven was adequate distribution.

- Combining *G. aculeifer* and *T. montdorensis* provided excellent control of WFT in the greenhouse. It was not necessary to release *G. aculeifer* separately on the ground; the mites could be released together on the lettuce plant without reducing their efficiency.

- Control of WFT by predatory mites on a commercial lettuce farm was compared to conventional chemical control. *T. montdorensis* alone or with *G. aculeifer* reduced WFT populations as well or better than normal commercial practice.

Cultural practices

- It was shown that leaving a few plants infected with TSWV in a greenhouse could lead to rapid spread of the disease. Symptoms of

TSWV spread as their insect vector moved through the crop. After 23 days, 56% of lettuces were infected with the virus.

- A survey of weeds growing on Sydney Basin hydroponic lettuce farms found that, on average, five alternate hosts of WFT or TSWV were present, with two of these being hosts to both.

- Although most growers understand that they should remove diseased plants, knowledge of the best way to do this is patchy, while others do not understand the infective role of specific weed species around the farm. Effectively controlling weeds and removing diseased plants could greatly reduce pest and disease pressure.

- WFT was demonstrated to be more attracted to yellow than blue. Yellow sticky tape placed in potentially high insect traffic areas can be used to intercept WFT before it reaches a crop.

- Many growers use tractor driven blowers to apply pesticides. Coverage by the blower was compared to a boom spray, knapsack and ute-pack. The blower was far less effective than any other method (average coverage 20-50%). The ute-pack was the best method, averaging 90-100% coverage. Incomplete coverage may not control the pest and increases development of insecticide resistance.

While there is considerable evidence that chemical control of WFT is increasingly ineffective, transitioning to IPM is not easy for many growers. Other HAL funded projects, such as HAL project number VG03098, have demonstrated that growers need significant assistance to change from chemical focussed solutions to ones involving biological control agents, cultural methods and reduced risk pesticides. In the case of WFT in hydroponic lettuce, growers may have little choice but to make the transition to IPM if they are to avoid economic damage to their crops. Implementing IPM requires time, attention, knowledge and commitment. However, as this project has demonstrated, with producers supporting the registration of the reduced-risk pesticides, for example, the results can be excellent.

Recommendations

This project has improved understanding of western flower thrips and the associated disease, tomato spotted wilt virus within hydroponic lettuce production systems. Cultural management strategies, reduced risk pesticides and biological control agents are now available to growers to help mitigate the effects of the insect pest. Whilst the reduced-risk pesticides are yet to be registered in these crops, the biological control agents are available now (http://goodbugs.org.au) The following recommendations are made to ensure that growers have the tools to manage WFT incursions in lettuce crops.

- The companies producing the reduced-risk pesticides HGW86, Agri50NF and Biocover are actively encouraged to seek registration of these products in hydroponic lettuce crops. These pesticides have high efficacy and are compatible with integrated pest management and biological control.

- Hydroponic lettuce growers should be supported and trained in the use of the biological control agents *Transeius montdorensis* and *Geolaelaps aculeifer* to ensure they are used effectively in control of WFT. This should include removal of pesticide residues from cropping areas and training in compatible chemicals.

- High traffic areas of WFT on farms should be identified and the use of sticky ribbon trialled on a larger scale. Barriers of sticky ribbon should be installed in such areas to intercept adult WFT.

- Routine use of blowers to apply pesticides in hydroponic lettuce should be actively discouraged. Insufficient coverage is being provided by this strategy with high risks of both ineffective control and increased pesticide resistance.

- A series of workshops should be presented to growers to highlight the findings and educate them on how to use the tools developed in this project. Historically (HAL Project Number VG03098 for example) it has been shown that one-on-one help for growers has resulted in increased uptake and adoption and this should also be considered.

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Acknowledgments

The project team would like to thank and acknowledge the financial contribution and support of Ausveg, Horticulture Australia Ltd and NSW Department of Primary Industries.

The growers and industry members that contributed their time and provided invaluable assistance during field trials or workshops are sincerely thanked for their commitment and assistance to the program.

Appendix A

Australian Entomological Society's 39th Annual General Meeting and Scientific Conference, Orange, New South Wales, September 28 – October 1, 2008.

Let us stick to it – sticky ribbon as a management strategy for western flower thrips in hydroponic lettuce

Pilkington, L. J., K. A. Coutts & L. J. Spohr
NSW Department of Primary Industries, Gosford Horticultural Institute, Locked Bag 26, Gosford, NSW 2250

The insect pest *Frankliniella occidentalis* (Pergande) (Thripidae: Thysanoptera), western flower thrips (WFT), has proved to be a major pest in Australian agriculture since the early 1990s, mainly because of the insect's ability to vector several diseases including tomato spotted wilt virus. The management of WFT in hydroponic lettuce is made difficult by the lack of registered pesticides. A key component of an integrated pest management strategy is the prevention of pests from entering and subsequently feeding on a crop causing physical damage and introducing pathogens. Blue and yellow sticky ribbon is a product with sticky glue on both sides available from a number of manufacturers in widths of 5 cm to 30 cm and lengths up to 500 m. It is sold as a monitoring tool and a trapping method to reduce numbers of flying insects. Similar to blue and yellow sticky traps used to routinely monitor flying insects in Australian greenhouses, they are supplied as a continuous roll and allow the user to position large surfaces of sticky ribbons in areas likely to experience heavy pest pressure or movement, such as along ventilation windows, at the start of crop rows or directly above the crop. An experiment was undertaken to evaluate and compare the effectiveness of 15 cm blue and yellow sticky ribbon ('Rollertrap', Koppert BV, Netherlands) to trap WFT and assess the ribbon's ability to reduce WFT numbers entering the lettuce crop and the reduction in population size within crop as a result. Several different positions of the sticky ribbon were evaluated for their trapping efficacy. Data analysis indicated a statistically significant effect for ribbon colour and a numerical indication that ribbon, regardless of colour, inhibited movement of WFT onto the lettuce when positioned around the plant. Results will be presented and discussed.

Lettuce LET US STICK TO IT – STICKY RIBBON AS A MANAGEMENT STRATEGY FOR WESTERN FLOWER THRIPS IN HYDROPONIC LETTUCE

Leigh J. Pilkington[1], Katrina A. Coutts[1] and Lorraine J. Spohr[1]

INTRODUCTION

Since the early 1990s *Frankliniella occidentalis* (Pergande) (Thripidae: Thysanoptera), western flower thrips (WFT), has proved to be a major pest in Australian agriculture. The main concern is due to the insect's ability to vector several diseases including tomato spotted wilt virus. The management of WFT in hydroponic lettuce, and many crops, is made difficult by the lack of registered pesticides for growers to use, and those available often have reduced efficacy due to resistance build-up.

Growers are seeking additional techniques to manage this pest and a key component of an integrated pest management (IPM) strategy is preventing pests from entering and feeding on a crop causing physical damage and introducing pathogens. A possible tool to assist this means is the use of blue and yellow sticky ribbon, a product with sticky glue on both sides available from a number of manufacturers in widths of 5 cm to 30 cm and lengths up to 500 m. Similar to blue and yellow sticky traps used to routinely monitor flying insects in Australian greenhouses, they are supplied as a continuous roll and allow the user to position large surfaces of sticky ribbons in areas likely to experience heavy pest pressure or movement, such as along ventilation windows, at the start of crop rows or directly above the crop.

An experiment was undertaken to evaluate and compare the effectiveness of 15 cm blue and yellow sticky ribbon ('Rollertrap', Koppert BV, Netherlands) to trap WFT and assess the ribbon's ability to reduce WFT numbers entering the lettuce crop and the reduction in population size within crop as a result. Several different positions of the sticky ribbon were evaluated for their trapping efficacy.

NSW DEPARTMENT OF PRIMARY INDUSTRIES

METHODS

Four replicates of five treatments (two tape colours, blue and yellow; two tape positions, above and around; and negative control) arranged in a two dimensional design allowed for variation in two directions. Two rows of lettuces with two replicates were surrounded by propagated weed plants with artificial infestations of WFT. Numbers of WFT were counted on sticky ribbon (both sides) and from one randomly selected lettuce plant weekly.

RESULTS

Significantly more insects were found in yellow traps compared to blue traps. Traps which were placed above the lettuce plants caught more than those placed around the plants.

Significantly less adult WFT were observed in lettuce when traps had been placed around the plants compared to lettuce when traps had been placed above. This effect was consistent regardless of the colour of the trap.

The overall effect of traps compared to no traps on the number of WFT adults in lettuce was not significant.

ACKNOWLEDGEMENTS

This project is facilitated by HAL in partnership with NSW DPI. It is funded by the vegetable industry levy. The Australian Government provides matched funding for all HAL's R&D activities. NSW DPI is a member of the The E H Graham Centre for Agricultural Innovation, a collaborative alliance between Charles Sturt University and the NSW Department of Primary Industries.

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SYMPOSIA & WORKSHOP

Pest & Disease Management of Field & Hydroponic Lettuce

UWS Hawkesbury Conference Centre

Wednesday 28th November 2007
9.30 am – 4.30 pm

Management tools for *Frankliniella* occidentalis in hydroponic lettuce – mites might work. Is biocontrol spreading its wings in Australia?

Pilkington, L. J.
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In Europe and other parts of the world, there is no doubting the utility of biological control agents when used within a greenhouse production system. In Australia, the use of biological control agents is beginning to be widely used as a very successful management tool in many styles of greenhouses and in many different crops. Australian growers are now enjoying a supply of a broad range of biological controls and can now often target the pest with different organisms that attack either different life stages or different areas of the host plant. In a Horticulture Australia Ltd project, a combination of predatory mites *Transieus montdorensis* and *Geolaelaps aculeifer* were tested for control of *Frankliniella occidentalis*, western flower thrips, on hydroponic lettuce. Using two very different strategies the two organisms affected numbers of the pest in indoor and outdoor trials. Results from this work and similar examples of other complementary systems will be discussed.