Evaluation and Demonstration of Two-Spotted Spider Mite Biological Control in New Jersey High-Tunnel Vegetable Production

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Summary

From 2002-2004, Rutgers Cooperative Research and Extension Vegetable Integrated Pest Management (IPM) Program personnel worked with growers who used semi-permanent polyethylene greenhouses, known as high tunnels, to produce warm season vegetables crops earlier in the year. The project was initiated to determine the viability of biological control of the two-spotted spider mite (TSSM) under high tunnel conditions. The main biological control agent; *Neoseiulus fallacis* provided acceptable control or suppression in all cases where TSSM was present and *N. fallacis* was released. Leaf brushing samples indicated extended predator presence in zucchini and pepper, as well as movement among tunnels in one multi-tunnel complex. Long term predator establishment was not as successful when tomato was the crop, but TSSM suppression occurred. Participating growers were enthusiastic about the project and planned to include TSSM biocontrol as a management tool in an extension based IPM program.

General Plan of Work

The reporting on this project spans three years, from 2002-2004. A New Jersey Agricultural Experiment Station Program Enhancement Grant provided funding for the first year of the project. The results of the first year are included here since the second two years were a continuation of the project funded by the EPA.

Grower participants were segregated into a northern group (individual farms in Mercer, Hunterdon, Warren, and Morris counties), and a southern participant in Cedarville, Cumberland County. Grower participation changed somewhat from year to year. This was typically due to changing crop production practices, i.e. switching from vegetable crops to hay production for one season; or in one case, because of weather related destruction of the high tunnel. One new high tunnel in Warren County northern location was included in 2004 (Phillipsburg) at that growers' request.

The phytoseiid mite, *Neoseiulus fallacis* Garman, is a predator of tetranychid mites, including *Tetranychus urticae* (Koch), the two-spotted spider mite (TSSM). *N. fallacis* is often associated with biological control in orchards and brambles and was selected for this project because of its somewhat broader temperature tolerance than the more commonly used greenhouse biocontrol agent *Phytoseiulus persimilis* Athias-Henriot. Additionally, *N. fallacis* is capable of feeding on pollen to avoid starvation in the absence of mite prey, while *P. persimilis* is an obligate TSSM predator. *N. fallacis* is also noted for its' dispersal abilities.

In 2002, six growers volunteered a total of 20 high tunnels. Zucchini was grown in the 14 tunnel complex in Cedarville, Cumberland County. In the six northern tunnels, the crop was tomato. The latter tunnels were situated in Mercer (Hopewell), Hunterdon (Jutland (2), Sand

Brook), Morris (Denville), and Warren (Blairstown) counties. Histories of TSSM problems in the tunnels ranged from none to severe.

Scouting in the Cedarville zucchini tunnels commenced on April 25, and was conducted once a week. In each tunnel, the protocol was to observe two leaves each on 10 plants per tunnel. Predatory mites (*N. fallacis*) were purchased from Green Methods (Nottingham, NH), and released on May 1 in selected tunnels, at a rate of approximately 9.5/ yd^2 of floor space. The release rate equated to one half vial (2500 mites) of *N. fallacis* per tunnel, at a cost of approximately 25 dollars. The number of tunnels in the Cedarville zucchini complex permitted variable treatments, with *N. fallacis* released in several tunnels and the systemic insecticide imidacloprid (Admire) used at planting in other tunnels including some where *N. fallacis* was released. Admire was intended for prevention of cucumber beetle feeding and aphids. TSSM infestation was recorded as number of leaves with mites. Beginning on May 7, and continuing for every two weeks until June 28, five leaves per 100 plants per house were collected and brought to the lab for brushing. After the leaves were removed, they were placed in locking polyethylene bags, separated by tunnel. The leaves were then run through a mite brush (Leedom Enterprises, Mi Wuk Village, CA.), and all arthropods brushed from the leaves were counted.

Scouting for mites in the tomato high tunnels was conducted as part of the regular tomato IPM scouting program. Within each tunnel, five consecutive plants were selected at five random sites. On each plant, two complete leaves from the low to mid canopy were observed for the presence of TSSM. Initial predator releases were made in all tunnels on 5/16 (except Denville (6/12)). Release rates in these tunnels were somewhat higher (approx. 15/yd^2) than in the zucchini tunnels based on tunnel size when one-half vials (2500) of *N. fallacis* were used. A second predator release was made on 6/27 at Sand Brook, and Jutland 1. Removal of leaf samples for brushing began May 13 except at Denville, where the first samples were removed June 12. The sample size in the northern tomato tunnels was one complete lower leaf per plant on five consecutive plants in three locations for a total of 15 leaves per tunnel. Leaf brushing samples were removed every 2 weeks through June 25. Exceptions to the brushing protocol occurred at Denville (June 12), and Hopewell (May 14). In these cases, insufficient foliage made leaf removal impossible. Instead, the same number of leaves was examined thoroughly with hand lenses to determine the type and quantity of arthropods present.

HOBO Pro Series (Onset Computer Corp. Pocasset, MA.) data loggers were used to measure temperature (°F), and relative humidity (%RH) in all tunnels to determine whether negative biocontrol performance was linked to environmental extremes.

Initially, *P. persimilis* was to be released into tunnels where TSSM appeared after the initial release of *N. fallacis*. This plan was abandoned because the lower temperature and higher humidity requirements for *P. persimilis* were felt to be unattainable in the high tunnels, particularly later in the season. Instead, second releases of *N. fallacis* were made.

Harvest information was recorded for each tunnel, although the unreplicated nature of the northern tomato high tunnels resulted in this information being a subjective measure of grower satisfaction with the crop and pest control. Growers were asked for their impressions of the cost of this type of biocontrol relative to the cost of applying conventional miticides.

In the second year, 2003, 4 growers volunteered a total of 19 high tunnels. Sixteen tunnels were on the farm in Cedarville, Cumberland County. The others were individual tunnels at Hopewell, Mercer County; Sand Brook, Hunterdon County; and Blairstown, Warren County. The Jutland location was not included as the grower opted to switch from vegetable to hay production. The Denville high tunnel suffered snow damage and was not utilized in 2003. The crop was tomato in all participating tunnels.

In May of 2003, RCE IPM staff released *N. fallacis* into all tunnels (except selected tunnels at Cedarville) at rates of approximately 9-15/yd^2 of floor space. At the Blairstown location, a low level TSSM population was present at the time of predator release. As in 2002, regular scouting was conducted to assess the level of injury from TSSM, and overall plant health in general. In addition, leaves were sampled and brushed bi-weekly to determine the relative levels of predator and TSSM. Secondary releases of *N. fallacis* were not to be made as long as TSSM was not present. In the Sand Brook and Blairstown tunnels, an additional release of the obligate TSSM predator *Stethorus punctillum* Weise, a small ladybird beetle, was made late in the crop cycle at a rate of 1.2/ yd^2. These releases were in response to late season increasing TSSM populations with regular daily temperatures in excess of that considered favorable for *N. fallacis* survival. *S. punctillum* withstands higher temperatures and lower relative humidity than *N. fallacis*. Temperature and relative humidity was monitored for the duration of the study. Harvests were considered good except at Hopewell, which was flooded following heavy spring rains, and Blairstown, which received insufficient water and did not produce many marketable fruit.

In 2004, six growers volunteered a total of 22 tunnels for the third year of the project. Many different varieties of peppers were grown in the 16 high tunnel complex at Cedarville. The systemic insecticide imidacloprid (Admire) was used at planting in all Cedarville tunnels to prevent aphid feeding and possible virus transmission. There were individual tunnels at Sand Brook (tomato), Hunterdon County; Blairstown (tomato) and Phillipsburg (pepper), Warren County; Hopewell (tomato), Mercer County; and two tunnels at Jutland (tomato), Hunterdon County. Because TSSM had not appeared regularly in all tunnels, it was decided that *N. fallacis* should only be released in response to TSSM detection in individual tunnels. Because tunnels were scouted 1-2 times a week, early detection of TSSM was assured, and allowed for favorable predator to prey ratios at release. Also, this method fit well with the way biocontrol was likely to be utilized in the scouting program once fully implemented. Leaf samples from tunnels were brushed bi-weekly to assess mite and/or predator levels. An exception to this procedure was the Phillipsburg high tunnel (pepper), which was a late addition to the project at the growers' request. Growers were surveyed regarding their impressions of the project, and the likelihood of their continuing to make TSSM biological control a part of their regular management plan for high tunnel vegetable production.

Results

2002

TSSM colonies were present in the Cedarville zucchini high tunnels and the Denville, Sand Brook and Jutland 1 tomato tunnels. None of the others developed TSSM populations. At Denville, the initial population of TSSM was very low, and disappeared completely within two weeks of the introduction of N. fallacis. *N. fallacis* was not recovered in brushing samples, and TSSM did not reappear. At Sand Brook, TSSM appeared as tomatoes were maturing in mid June. One release of *N. fallacis* had been made prior to this and one immediately after discovery of TSSM. TSSM increased slowly through July but tomato harvest was unaffected as the pest developed too late in the season. In 2001, this tunnel was lost to TSSM infestation, but in 2002, the population was possibly suppressed by the predator and resulted in successful harvests. In the Jutland 1 tunnel, TSSM was found in May and *N. fallacis* was released the same week. For the duration of the crop, TSSM levels were considered light, and *N. fallacis* was recovered periodically. In Jutland 2, TSSM was extremely light and very late. Neither tunnel was adversely affected by TSSM, and harvests were successful. No miticides were used in any tunnel.

N. fallacis, appeared to establish well in the Cedarville zucchini high tunnels, even to the extent that it was recovered from tunnels where it was not released (Fig.2). This apparent migration between houses was facilitated by the tunnels' open sides as well as close proximity (4') to others within the complex. Final brushing samples indicate a favorable predator to prey ratio, with *N. fallacis* generally increasing as TSSM populations decline.

Overall, yield in two zucchini varieties at Cedarville was unaffected by the presence or absence of a predator versus a systemic insecticide (Table 1), although the higher TSSM rates in leaf brushing samples came from tunnels where Admire was used (Fig. 2). This is consistent with reports that systemic use of imidacloprid results in increased TSSM populations on host crops. The tomato high tunnels were individual trials, and as such, were not replicated. Comparisons between tomato harvests were not made, but growers all expressed satisfaction with the amount and quality of fruit obtained from the tunnels. Harvests at the Blairstown site were depressed due to insufficient irrigation.

Environmental recording equipment in the tunnels showed that the tomato tunnels generally had longer and more frequent episodes of high temperature (> 85°F) and low relative humidity (RH < 50%) particularly later in the season. This is because tomatoes are a longer season crop than zucchini, and seasonal conditions overall were warmer in late June and July. The zucchini crop finished earlier, and missed some of the warmer summer weather. Additionally, the zucchini tunnels at Cedarville were bare ground, while the tomato tunnels had black plastic or landscape fabric on the floor. The coloration of this material may have been partially responsible for elevated temperatures and resulting low % RH. Plastic mulch also impedes the evaporation of water from the soil, and may have resulted in less humidity within the plant canopy. These conditions may have resulted in better *N. fallacis* establishment in zucchini as the predator is favored by higher % RH when temperatures are elevated. Also, the tomato leaf surface is covered with sticky glandular trichomes. *N. fallacis* is reported to have some difficulty with this surface, spending time cleaning the sticky exudate from its legs. Zucchini, having trichomes, but lacking sticky exudates was likely a more favorable leaf surface for the predator.

2003

The tunnel in Hopewell was abandoned at an early stage due to flooding as a result of excessive spring rains. At the Blairstown location, a low level TSSM population was present at the time of predator release. The predator was found in scouting samples among the TSSM colonies for a month following release, and TSSM colonies were reduced dramatically. *N. fallacis* was not recovered in brushing samples (data not shown). A low level TSSM infestation remained on a small number of plants in one spot in the tunnel, and this population increased to potentially damaging levels until late in the season as temperatures increased significantly. By this time however, the crop was in decline due to extreme high temperatures and insufficient root mass to sustain plant health. At Sand Brook, *N. fallacis* was released on May 23 despite the absence of TSSM. The predator was observed in the tunnel for just over a week after release. TSSM ultimately appeared late in the crop cycle at Sand Brook, as was the case in 2002. TSSM first appeared after brushing samples had ceased due to crop maturity. TSSM did not limit yields due to the advanced maturity of the crop. Having lost a crop to TSSM the season preceding the use of biocontrol, the grower felt that *N. fallacis* was delaying the development of destructive populations of TSSM. In the Sand Brook and Blairstown tunnels, an additional release of the obligate TSSM predator *Stethorus punctillum*, a small ladybird beetle, was made late in the crop cycle at a rate of 1.2/ yd^2. Each release of *S. punctillum* cost seventy-eight dollars. These releases were in response to increasing TSSM populations as well as regular daily temperature in excess of that considered favorable for *N. fallacis* survival. *S. punctillum* was purported to withstand higher temperatures and lower relative humidity than *N. fallacis*. *S. punctillum* was observed to immediately begin feeding on TSSM in the tunnels, however, within one week they had completely disappeared from both release sites despite the presence of prey. Temperatures in the tunnels were extremely high, particularly at the Blairstown site, where 110°F was observed the week following *S. punctillum* release. It is likely that temperatures within the tunnels were too high even for the heat tolerant beetle.

N. fallacis was released in May into five of the tunnels at the Cedarville complex and the predator was recovered in low numbers periodically in brushing samples through July (data not shown). However, TSSM did not develop in the tunnel complex until late July, and then only an extremely low population. As a result, evaluations of predator efficacy were not possible.

Yields were considered good where crops were not affected by poor growing conditions. No miticide applications were necessary in any tunnel. The appearance of TSSM populations later in the tunnel growing cycle, combined with the apparent early suppression of the pest by *N. fallacis*, and the preference of *N. fallacis* for moderate temperatures and higher humidity supports the conclusion that *N. fallacis* must be used early in the crop cycle. This way the predator can successfully suppress TSSM while temperatures favor the predator. As temperatures increase later in June and into July, conditions favor TSSM.

2004

The Sand Brook and Blairstown sites developed TSSM populations in late June and early July respectively. The Blairstown increase was directly related to the grower mowing down heavy weed growth around the outside of the tunnel. As the vegetation dried, TSSM moved into the tunnel. Past experience with *N. fallacis* and TSSM late in the tomato high tunnel crop cycle indicated that the predator would not perform well under higher temperature conditions at that time of the season. Since TSSM appeared as fruit were ripe or close to ripening, they would not adversely affect yield or fruit quality. As a result, *N. fallacis* was not released at these sites, with no negative impact on the crop. A light but widely dispersed population of TSSM was discovered at the Phillipsburg site on May 11, and *N. fallacis* was released on May 14 at a rate of 10/ yd^2. By May 18, TSSM was nearly eliminated from the tunnel, and did not reappear. *N. fallacis* remained active in the tunnel for several weeks after the introduction. Leaf brushing and environmental monitoring was not conducted at the Phillipsburg site as it was a late addition to the demonstration at the growers' request. TSSM did not develop at the Hopewell site, and N. fallacis was not released. Yields were considered good to excellent in these tunnels, and no miticides were used.

In the Cedarville pepper complex, low numbers of TSSM appeared by late in June, and *N. fallacis* was released in selected tunnels in early July. *N. fallacis* established well in tunnels where it was originally released and spread into all other tunnels. One tunnel where *N. fallacis* was not released developed a significant population of TSSM in late July. The grower responded with a miticide application in this tunnel, and other tunnels where *N. fallacis* had not been released. This application significantly reduced, but did not eliminate the TSSM population in the affected tunnel (Fig. 3). Other tunnels that were treated with miticide did not have damaging levels of TSSM originally, and some TSSM remained after treatment. In many tunnels, *N. fallacis* rebounded to levels similar to those prior to the miticide treatment (Fig. 3). Conditions in the tunnels became warmer with periods of lower relative humidity in late June, favoring TSSM. This was the period when TSSM began to appear. July however, was generally cooler with more humid conditions in the tunnels, likely favoring survival of *N. fallacis*. Bare ground culture in the Cedarville tunnels may have moderated humidity levels relative to the northern high tunnels. This may allow more evaporation of moisture from the soil, as opposed to tunnels where there is a less permeable plastic cover over the entire tunnel floor. Higher humidity favors the predator. Harvests were considered good in the Cedarville tunnel complex, and there were no differences among tunnels.

Grower Response

Grower response to TSSM biological control in the tunnels was unanimously positive. All are willing to utilize predatory mites in the future, although some expressed reluctance to use them without supervision from an IPM practitioner. This is largely due to the time limitations on the farm manager, where an IPM practitioner would be responsible for visiting tunnels and assessing pest levels on a regular basis. The cost of biological control was considered to be acceptable in that it was not significantly more than the total cost of applying a chemical, and the value of the crop enabled some extra expense. Safety risks associated with applying miticides in an enclosed area were a major issue as well. Growers considered the safety of biological control to more than offset the cost.

Conclusions

A number of important conclusions were derived from this project.

1. *Neoseiulus fallacis*, if deployed under favorable conditions is capable of providing satisfactory suppression of TSSM in high tunnel vegetable production in New Jersey. This assertion is supported by the successful suppression or elimination of TSSM in high tunnels at Sand Brook (02-04), Cedarville (02, 04), Blairstown (03-04), Denville (02), Jutland (02) and Phillipsburg (04).

2. *N. fallacis*, deployed in the absence of TSSM, is undetectable in a very short period of time. It is probable that in the absence of TSSM, *N. fallacis* quickly disperses out of the tunnels in search of prey.

3. Extended periods of high temperature (above 85°F) and corresponding low relative humidity levels (below 50%) that favor the rapid increase of TSSM on host crops are not ideal conditions for *N. fallacis*. These conditions are common late in June and into July in New Jersey high tunnels. As a result, first or second releases of *N. fallacis* late in the high tunnel crop cycle are not likely to be successful. Attempts to manage late season TSSM populations with the ladybird beetle *Stethorus punctillum* was unsuccessful and was likely due to high temperatures as well. Suppression of TSSM is achieved with releases of *N. fallacis* in April through early June.

4. There are times when it is unnecessary to release *N. fallacis*. This situation occurred frequently during the course of the project. If TSSM populations built up late, particularly at the Sand Brook and Blairstown sites, as the crown fruit were beginning to show color, the production of saleable fruit kept ahead of the destructive ability of the TSSM population.

5. Under reasonable conditions for *N. fallacis*, one release at a rate of 9-15 predators per yd^2 of high tunnel floor space is sufficient to achieve at least suppression of TSSM in high tunnel vegetables.

6. Crops with favorable leaf surfaces like pepper or zucchini are more likely to retain *N. fallacis* in the presence of TSSM than is tomato. Successful suppression of TSSM in tomato may be achieved if *N. fallacis* is deployed when TSSM is initially discovered at low levels.

7. Scouting vegetable high tunnels over several seasons, IPM staff recognized that TSSM is an annual pest in some locations, and is only occasionally problematic in others. If regularly scheduled scouting is occurring, releases of predatory mites may be made in response to the earliest detection of TSSM. This prevents wasted releases, yet still permits adequate suppression of the pest mites. Without regular scouting by someone able to identify TSSM at very low levels however, tactical releases of predatory mites would be risky given the ability of TSSM to increase rapidly.

Figure 1. *N. fallacis* (top left), two-spotted spider mites (bottom left), high tunnel interior (top right).

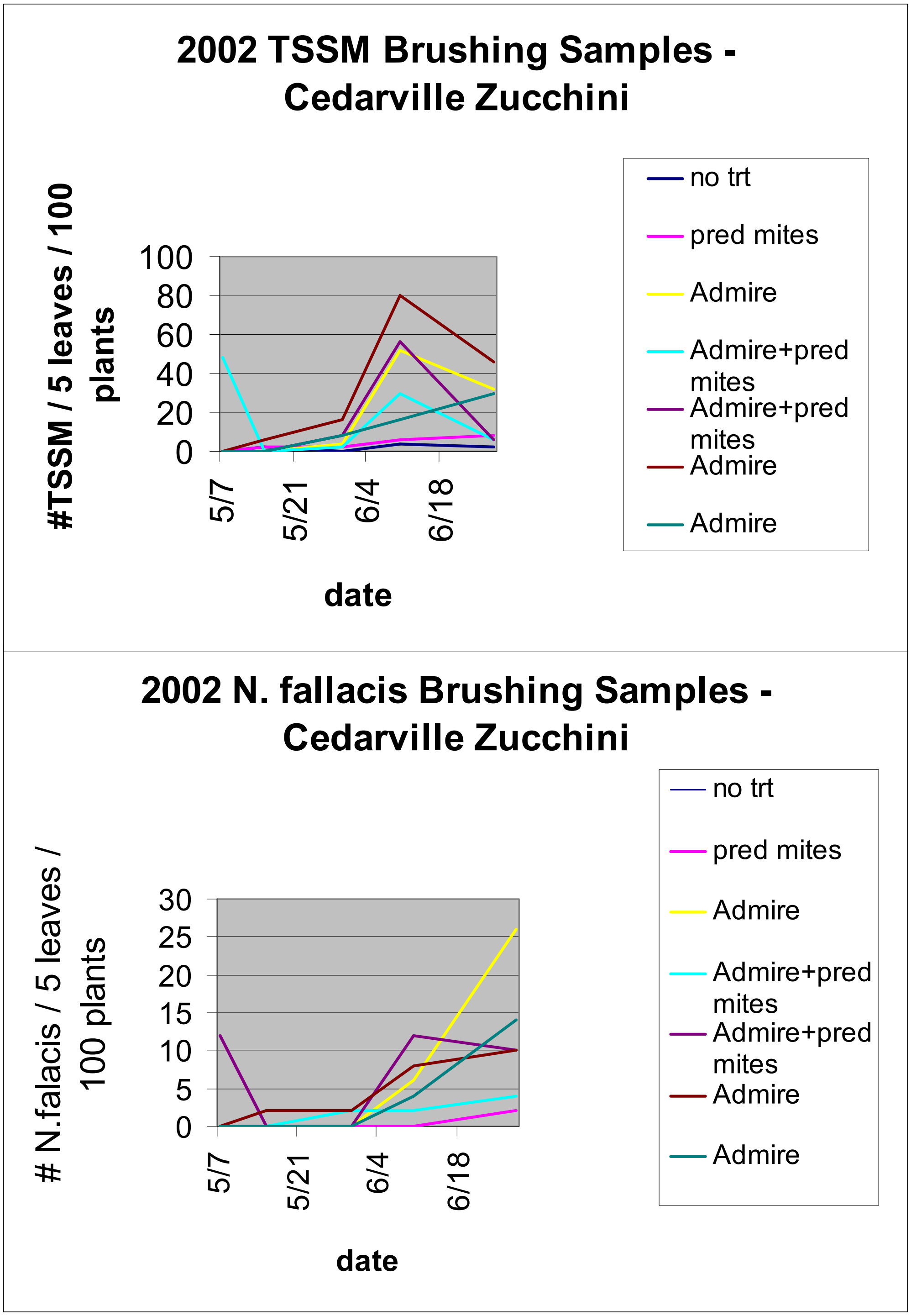

Figure 2. Relative populations of TSSM (top) and *N. fallacis* (bottom) on zucchini leaves from tunnels where imidacloprid (Admire) was used systemically alone or in combination with *N. fallacis*.

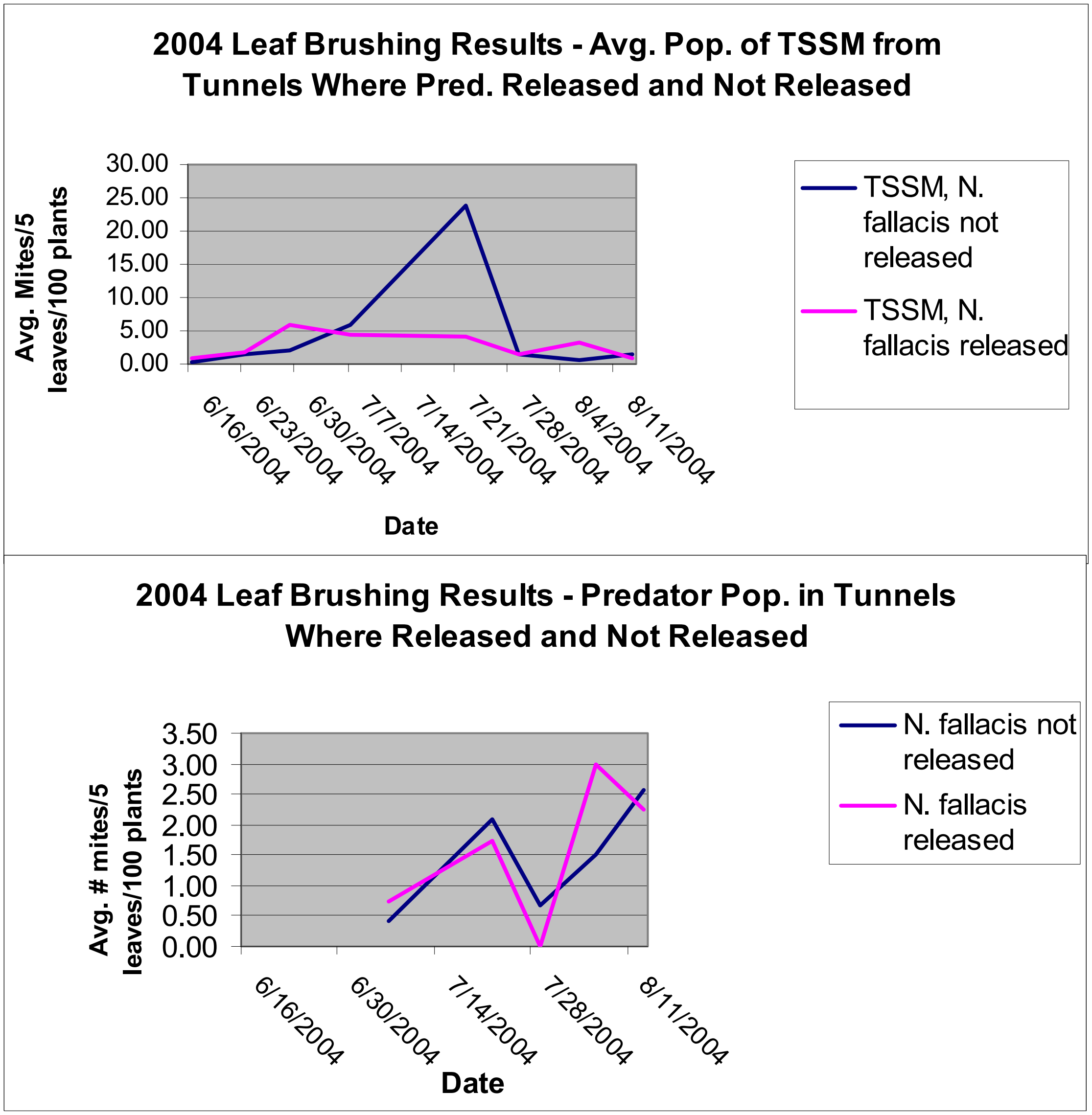

Figure 3. Relative populations of TSSM (top) and *N. fallacis* (bottom) on pepper leaves in tunnels where *N. fallacis* was released and where it was not released, but infiltrated.

Table 1. 2002 harvest data from Cedarville zucchini high tunnels.

Variety	Treatment	# Harvests	Avg. wt.(lbs)	Sig.
Cashflow	Admire	17	70.74	AB
	Admire+mites	17	72.96	AB
	Admire+mites	17	68.8	AB
	Admire	17	70.25	AB
	Admire+mites	17	74.30	AB
	Admire	17	76.62	A
	Admire	17	63.14	B
Revenue	No treatment	17	89.4	B
	Mites	17	105.07	A
	Admire	17	97.29	AB
	Admire+mites	17	88.75	B
	Admire+mites	17	88.42	B
	Admire	17	93.01	B
	Admire	17	89.96	B

ANOVA, DMRT, P=<.0001

Table 1. Harvest data from 2002 zucchini tunnels at Cedarville, showing differences among treatments.

Beneficial Suppliers:

Green Methods, Nottingham, NH
http://greenmethods.com/site/

IPM Labs, Inc.
http://www.ipmlabs.com/home.php

Biotactics
http://www.benemite.com/

Koppert Biological Systems
http://www.koppert.nl/e005.shtml