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Comparison of single and combination treatments of *Phytoseiulus persimilis*, *Neoseiulus californicus*, and Acramite (bifenazate) for control of twospotted spider mites in strawberries

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Abstract Greenhouse and field experiments were conducted from 2003 to 2005 to determine the effectiveness of combining releases of two predatory mite species, *Phytoseiulus persimilis* Athias-Henriot and *Neoseiulus californicus* (McGregor), and a reduced-risk miticide, Acramite® (bifenazate), for control of twospotted spider mite (TSSM) (*Tetranychus urticae* Koch) in strawberries. In the greenhouse experiment, a combination treatment of *P. persimilis* and *N. californicus* was compared with single treatments of each species, Acramite application, and untreated control. All treatments significantly reduced TSSM numbers compared with the control. Field studies employed two approaches: one investigating the same five treatments as the greenhouse experiment and a second, comparing combination treatments of *P. persimilis*/*N. californicus*, Acramite/*N. californicus*, and Acramite/*P. persimilis* to single treatments of each and to control plots. Among the combination treatments, the *P. persimilis*/*N. californicus* treatment significantly reduced TSSM numbers compared with the control, but was not as effective as *N. californicus* alone during the 2003–2004 field season. Also, combination treatments of Acramite/*N. californicus*, and Acramite/*P. persimilis* significantly reduced TSSM populations compared with the control. These findings indicate that all three combination treatments are promising options for TSSM control in strawberries for growers in northern Florida and other strawberry producing areas of the world.

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Introduction

In the United States, strawberries (*Fragaria* × *ananasa* Duchesne) are an important crop with annual revenue exceeding $1.4 million USD (NASS-USDA 2005). The twospotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae) is the major arthropod pest affecting field and greenhouse grown strawberries (Oatman and Mc Murtry 1966; Howard et al. 1985; Price and King 1991). Elevated levels of stress caused by high populations of TSSM can lead to a significant reduction in vegetative growth and flower development, which can decrease the quality and quantity of mature fruits (Sances et al. 1982).

To avoid economic losses resulting from high populations of TSSM in strawberries, cost effective management tactics must be implemented on commercial farms. In 1993, Trumble and Morse attempted to calculate the economic benefits of suppressing TSSM populations with pesticides in conjunction with releases of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot. The pesticides used in their study included Abamectin, Savey 2SF (hexythiazox), and Vendex 50%WP (fenbutatin oxide). They found that applications of abamectin in combination with releases of *P. persimilis* generated the best economic returns among the treatments evaluated. Abamectin is a natural product derived from the soil bacterium *Streptomyces avermitilis* Kim and Goodfellow that has been shown to have low toxicity to the predatory mite *P. persimilis* (Zhang and Sanderson 1990). Acramite® (bifenazate), a reduced-risk miticide (United States Environmental Protection Agency), has been shown to be much less toxic to adult female and immature *P. persimilis* than to adult female and immature stages of TSSM (Ahn et al. 2004; Kim and Yoo 2002; White 2004). Acramite has also been reported to be effective against TSSM in field grown strawberries (White 2004).

The predatory mite *Neoseiulus californicus* (McGregor) has been shown to effectively control TSSM on strawberries in Argentina (Greco et al. 1999; Greco et al. 2005), California (Oatman et al. 1977a, b), and north Florida (Rhodes and Liburd in press). Though no studies have been conducted in the field, Sato et al. (2002) found that abamectin is very toxic to *N. californicus* in the laboratory, causing initial mortality rates of up to 57.5%. In contrast, Acramite has low toxicity towards *N. californicus* in the laboratory (Veire and Tirry 2003; White 2004).

Inundative releases of predatory mites are generally recommended on commercial strawberry farms where high populations of TSSM exist (Veire and Price 1994). However, an application of a reduced-risk miticide is generally recommended to reduce TSSM pressure when the population exceeds economic threshold (ET) level. For instance, for North Florida, the threshold recommended is >5 in 100 leaves infested with TSSM (Liburd et al. unpublished data). Subsequent applications of selective miticides may also be necessary to adjust the prey/predator ratio (Field and Hoy 1986) and to maintain adequate long-term control of TSSM (Easterbrook 1992). Combination treatments of Acramite® with *P. persimilis* or *N. californicus* (McGregor) may be an effective strategy to reduce populations of TSSM in commercially grown strawberries.

Lee and Lo (1989) suggested a combination of releases of *P. persimilis* and *N. fallacis* (Garman) to control TSSM on strawberries in Taiwan. Therefore, it is possible that a combination of *P. persimilis* and other species in the genus *Neoseiulus* such as *N. californicus*, a native North American species, could be an effective treatment strategy to control TSSM on strawberries. Schausberger and Walzer (2001) showed this to be a viable option on gerbera plants in the greenhouse.

The purpose of these experiments was to determine the effectiveness of three combination treatments: (1) *P. persimilis*/*N. californicus*, (2) Acramite/*N. californicus*, and (3) Acramite/*P. persimilis* and to compare them with single treatment applications for control of TSSM in strawberries. Greenhouse studies examined only the *P. persimilis*/*N. californicus* combination treatment, while field studies examined all three combinations.

Material and methods

Experiment I: greenhouse experiment

The mites

A TSSM colony reared on potted strawberries was maintained in the laboratory to ensure that only TSSM exposed to strawberries were used in the experiments. The colony was kept at a photoperiod of 14:10 (L:D) h regime at ~27°C with 65% RH. Strawberry plants were watered twice weekly.

Predatory mites used in all experiments were obtained from Koppert Biological Systems, Inc. (Romulus, MI) and were used within 48 h of their arrival dates. A representative sample (the material from one bottle of each species of predatory mite) was carefully observed for at least 15 min to ensure that the majority of the predatory mites were alive and active prior to use.

Greenhouse trial

Twenty-five mite-free potted strawberry plants var. 'Festival' with five mature trifoliates were placed into previously constructed clean cages. Cages ($60 \times 30 \times 20$ cm) were constructed of a bag of nylon fabric with velcro on three sides (to allow easy access to the strawberry plants) supported by a tomato cage. The fabric was attached to the strawberry pot using a pull cord sown into the bottom of the cage. Cages were arranged in two rows and spaced at least 0.3 m apart to prevent predators from walking from one cage to another. Cages were used to keep both TSSM and predatory mites from dispersing between plants.

At least one week prior to predatory mite release, 10 TSSM were released onto each plant and allowed to multiply. Releases were done by using an insect pin to transfer adults from colony leaves onto the leaves of the caged strawberry plants.

Prior to the release of adult female predatory mites, one leaflet was collected from each plant and the number of TSSM motiles and eggs on each leaflet was counted. For the purpose of this study, the term ''motile'' includes all life stages excluding eggs. The average number of TSSM motiles and eggs per leaflet was calculated.

Experimental design was a completely randomized block with 10 replicates and 5 treatments. Two trials of this experiment consisting of 5 replicates each were

conducted: the first in December 2004/January 2005, and the second in March/April 2005. A replicate consisted of one plant with five mature trifoliates. Treatments included: (1) 10 *P. persimilis* released per infested plant, (2) 10 *N. californicus* released per infested plant, (3) 5 *P. persimilis* and 5 *N. californicus* released per infested plant, (4) Acramite 50WS® sprayed onto each infested plant at the recommended rate of 1.125 kg product per hectare, and (5) untreated (control) plants. Predator releases were done as designed above for TSSM at a ratio of 10:1 (10 TSSM motiles to 1 adult female predatory mite). Predatory mites were transferred to the caged plants from a petri dish one by one using an insect pin.

The population of predators and TSSM was sampled by taking one leaflet from each plant (5 leaflets from each individual treatment). Only one cage was opened at a time and each leaflet was kept in an individual zip lock bag. TSSM and predatory mites (motiles and eggs) on these leaflets were counted once each week over a 4 week period using a dissecting microscope.

TSSM motile and egg data were log transformed to normalize the data set and equalize the variances. Average TSSM per leaflet was compared across treatments from both trials using repeated measures ANOVA and means were separated using a Least Significant Difference (LSD) test. Predatory mite data were compared using a student's *t* test or a Satterthwaite *t* test depending on whether or not the variances were equal. Variances were compared using Levene's test and normality was checked using the proc plot function of SAS (SAS Institute 2002).

Experiment II: field experiment

2003–2004 field season

This experiment was conducted at the University of Florida, Plant Science Research and Education Unit (PSREU), Citra, FL. Strawberry plants var. 'Festival' were planted in mid October. They were grown as an annual crop on raised beds covered by black plastic mulch. A combination of overhead and drip irrigation was used for the first 3 weeks to help establish the transplants. After this establishment period, only drip irrigation was used. Strawberries were planted in plots 7.3×6.1 m consisting of six rows 0.5 m wide spaced 0.5 m apart. Twenty plots were arranged in a 4×5 grid and were spaced 7.3 m apart. The experiment was a completely randomized block design with four replicates. Five treatments were evaluated: (1) two releases of a full rate of *P. persimilis* (P), (2) two releases of a full rate of *N. californicus* (N), (3) two applications of Acramite 50WS® (A), (4) two releases of a 1/2 rate of *P. persimilis* and a 1/2 rate of *N. californicus* (P/N), and (5) an untreated control (C). Predatory mites were released at a rate of ~ one predatory mite for every 10 TSSM motiles (1 bottle per plot) by hand by gently rotating the bottle over each plant. The half release rate was ~ one predatory mite per 20 TSSM motiles (1/2 bottle per plot). Acramite 50WS® was applied using an 11.4 L Backpack sprayer at the rate of 1.125 kg product per hectare. Treatments were applied during the weeks of December 11 and February 11.

2004–2005 field season

This experiment was conducted at PSREU following the same procedures as the 2003–2004 field season. The experiment was a completely randomized block design

with four replicates. Seven treatments were evaluated: (1) two releases of *P. persimilis* (P), (2) two releases of *N. californicus* (N), (3) two applications of Acramite 50WS® (A), (4) two releases of both *P. persimilis* and *N. californicus* at half the release rate (P/N), (5) two applications of a half rate of Acramite and two releases of *N. californicus* at half rate (A/N), (6) two applications of a half rate of Acramite and two releases of *P. persimilis* at half rate (A/P), and (7) an untreated control (C). Treatments were applied on December 9 (at week 4 as in the previous field season) and March 10 (delayed so TSSM populations could have a chance to build up). Predatory mite releases were done within 24 h of Acramite application utilizing the same methods as the previous field season.

Sampling protocol and data analysis

Sampling was conducted once per week after the plants had established (1 month after planting). This occurred on the week of November 21 in both field seasons. Leaflets were collected from the middle and lower strata of each plant. Each week, six leaflets per plot (24 leaflets per treatment) were randomly collected and taken to the laboratory where the number of TSSM motiles and eggs on each leaflet were counted under a dissecting microscope. After predators were released, the numbers of predators and their eggs were also counted.

The TSSM motile and egg data were separated into five periods based on treatment application dates and time during the season to help normalize the data. This was also important to examine trends throughout the four-month field season. Periods included: (1) pre-treatment (3 week prior to first treatment), (2) early-season (post-treatment to week 7), (3) mid-season (week 8 to when the second treatment was applied in the 2003/2004 season on week 12), (4) early-late season (week 13 to when the second application was applied in the 2004/2005 season at week 16), and (5) late season (week 17–19). The late season was split into two periods because of the difference in timing of the second application between seasons. In each period, data were log transformed to normalize the data sets and equalize variances and then treatments were compared using an ANOVA. Means were separated using a LSD test. Predatory mite data from 2003 to 2004 were compared using Satterthwaite t tests for unequal variances. Predatory mite data from 2004 to 05 were compared using an ANOVA. Variances were compared using Levene's test and normality was checked using the proc plot function (SAS Institute 2002).

Results

Greenhouse experiment

There were an average of 8.6 ± 2.5 motiles per leaflet in the control. This was significantly higher than the *N. californicus*, *P. persimilis*/*N. californicus*, and Acramite treatments, which averaged 0.6 ± 0.3, 1.6 ± 0.5, and 0.3 ± 0.1 motiles per leaflet respectively ($F = 4.1$, df = 4,170, $P < 0.05$). The *P. persimilis* treatment, which averaged 4.6 ± 2.3 motiles per leaflet, was not significantly different from the control or the other three treatments. When weekly trends were observed (Fig. 1a), it was interesting to note that TSSM motile numbers in the *P. persimilis* treatment increased greatly at week 4.

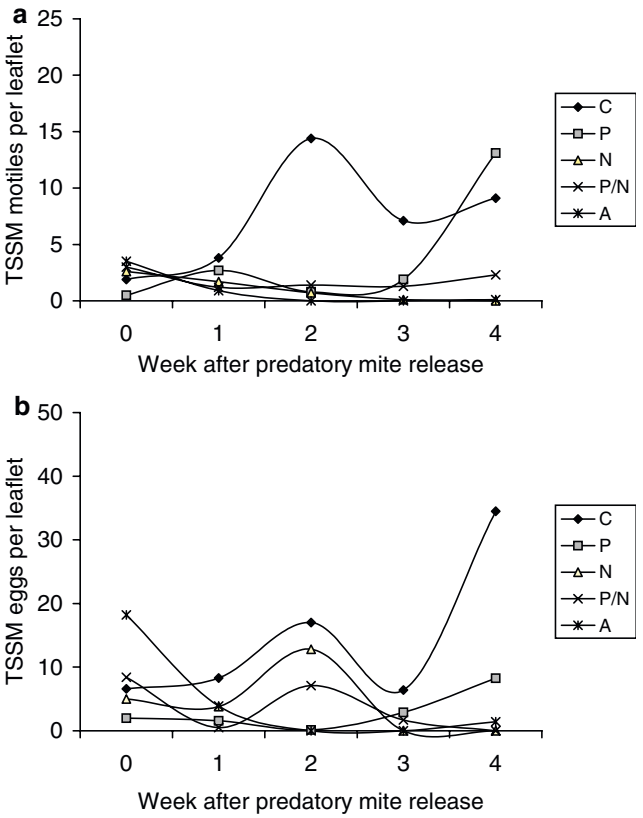

Fig. 1 Weekly average TSSM **(a)** motiles and **(b)** eggs per leaflet in each treatment in the greenhouse experiment. Week 0 is the initial sample taken before predatory mites were released. (C = control, P = *P. persimilis*, N = *N. californicus*, P/N = *P. persimilis*/*N. californicus* combination, and A = Acramite)

A somewhat different trend was noted when observing the TSSM egg numbers. The control averaged 42.0 ± 27.0 eggs per leaflet. This was significantly higher than all of the other four treatments, which averaged 4.4 ± 2.3, 4.2 ± 3.3, 2.3 ± 1.7, and 1.3 ± 0.9 eggs per leaflet in the *P. persimilis*, *N. californicus*, *P. persimilis*/*N. californicus*, and Acramite treatments respectively ($F = 4.0$, df = 4,170, $P < 0.05$). When weekly trends were observed (Fig. 1b), a slight increase in TSSM egg numbers in the *P. persimilis*treatment at week 4 is indicated, but it is much less dramatic than what was observed for TSSM motile numbers.

Predatory mites

One week after predatory mite release, no *P. persimilis* motiles were recorded in the *P. persimilis* treatment. However, at week 2 there were an average of 0.5 ± 0.3 motiles per leaflet. This declined to 0.1 ± 0.1 motiles per leaflet at week 3 and remained low at week 4. Only one *P. persimilis* egg was recorded throughout the study.

In contrast, *N. californicus* numbers in the *N. californicus* treatment increased from an average of 0.1 ± 0.1 at week 1 to 0.4 ± 0.2 at week 2 and then remained at this level for the remaining 2 weeks. In total, only 3 eggs were laid during the experiment.

In the *P. persimilis*/*N. californicus* treatment, *P. persimilis* motiles were not recorded until week 3 (at 0.4 ± 0.4 motiles per leaflet) and no *P. persimilis* eggs were recorded. In contrast, *N. californicus* motiles and eggs were recorded during all 4 weeks of the study. Numbers increased from an average 0.1 ± 0.1 motiles per leaflet at week 2 to 0.8 ± 0.5 motiles per leaflet at week 4. Only a few eggs were recorded each week.

There were no significant differences in numbers of *P. persimilis* motiles and eggs between the *P. persimilis* and *P. persimilis*/*N. californicus* treatments (motiles, $t = 0.16$; df = 71; $P = 0.87$; eggs, $t = 0$, df = 78, $P = 1.0$). There were also no significant differences in numbers of *N. californicus* motiles and eggs between the *N. californicus* and *P. persimilis*/*N. californicus* treatments (motiles, $t = 0$, df = 78, $P = 1$; eggs, $t = -0.92$, df = 63.1, $P = 0.36$).

2003–2004 field season

In the pre-treatment period, there were statistically significant differences in TSSM motile numbers between treatments ($F = 3.3$, df = 4,12, $P < 0.05$) (Fig. 2a). However, there were no significant differences in egg numbers during this period ($F = 0.90$, df = 4,12, $P = 0.49$). There were no significant differences in TSSM motile and egg numbers between treatments in the early-season (motiles: $F = 0.35$, df = 4,12, $P = 0.84$; eggs: $F = 0.27$, df = 4,12, $P = 0.49$) (Fig. 2a, b). In the mid-season, the control and *P. persimilis* treatments had a trend of higher numbers of TSSM motiles and eggs when compared with the Acramite treatment, but the differences were not statistically significant (motiles: $F = 2.4$, df = 4,12, $P = 0.11$; eggs: $F = 2.5$, df = 4,12, $P = 0.10$) (Fig. 2). In the early-late season, the control had significantly higher numbers of TSSM motiles and eggs than the other four treatments, which did not differ significantly from each other (motiles: $F = 3.1$, df = 4,12, $P < 0.05$; eggs: $F = 3.4$, df = 4,12, $P < 0.05$) (Fig. 2). There were no significant differences in TSSM motile and egg numbers between any treatments in the late season (motiles: $F = 1.0$, df = 4,12, $P = 0.44$; eggs: $F = 1.0$, df = 4,12, $P = 0.44$) (Fig. 2).

Predatory mites

Phytoseiulus persimilis mites were observed in the mid and early-late seasons. In the *P. persimilis* treatment, the *P. persimilis* population reached a peak of 1.5 ± 1.0 motiles and 1.2 ± 0.6 eggs per leaflet. In the *P. persimilis*/*N. californicus* treatment the highest recorded numbers were an average of 0.2 ± 0.2 motiles and 0.1 ± 0.1 eggs per leaflet. Very few *P. persimilis* motiles or eggs were recorded from the Acramite, *N. californicus*, or control treatments.

Neoseiulus californicus mites were also observed in the mid and early-late seasons. In the *N. californicus* treatment, the *N. californicus* population reached a peak of 1.2 ± 0.7 motiles and 1.4 ± 1.4 eggs per leaflet. In the *P. persimilis*/*N. californicus* treatment, the *N. californicus* population peaked at an average of 1.1 ± 0.3 motiles and 0.4 ± 0.4 eggs per leaflet. No *N. californicus* motiles or eggs were recorded from the Acramite treatment and very small numbers were recorded from the *P. persimilis* and control treatments.

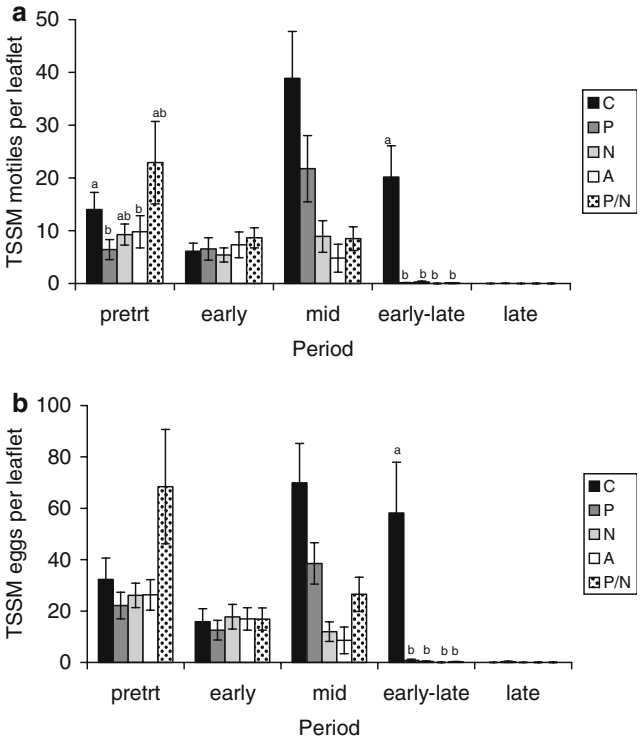

Fig. 2 Average TSSM **(a)** motiles and **(b)** eggs in five periods of the 2003/2004 season. Treatments with the same letter are not significantly different from each other. Error bars represent standard error of the mean. (C = control, P = *P. persimilis*, N = *N. californicus*, A = Acramite, and P/N = *P. persimilis*/*N. californicus*)

There were an average of 0.02 ± 0.01 *P. persimilis* motiles and eggs per leaflet in the combination treatment, which was significantly less than the *P. persimilis* treatment that averaged 0.2 ± 0.1 motiles and 0.3 ± 0.1 eggs per leaflet (motiles: $t = -3.38$, df = 469, $P < 0.0005$; eggs: $t = -3.78$, df = 467, $P < 0.0001$). In contrast, the number of *N. californicus* motiles and eggs in the combination treatment did not differ from those in the *N. californicus* treatment (motiles: $t = 0.11$, df = 866, $P = 0.46$; eggs: $t = -0.57$, df = 643, $P = 0.28$). There were an average of 0.1 ± 0.04 motiles and 0.07 ± 0.02 eggs per leaflet in the combination treatment and 0.1 ± 0.05 motiles and eggs per leaflet in the *N. californicus* treatment.

2004–2005 field season

Twospotted spider mite populations peaked much later in the 2004/2005 season than in the 2003/2004 season. There were no significant differences in TSSM motile numbers between treatments in the pretreatment period ($F = 1.0$, df = 6,18, $P = 0.46$) or in the early-season ($F = 0.65$, df = 6,18, $P = 0.69$) (Fig. 3a). There were no significant differences in TSSM egg numbers between treatments in the pretreatment period ($F = 0$, df = 6,18, $P = 1$) (Fig. 4a). In the early-season, however, there were significantly more TSSM eggs in the *P. persimilis* treatment compared with the control and all three

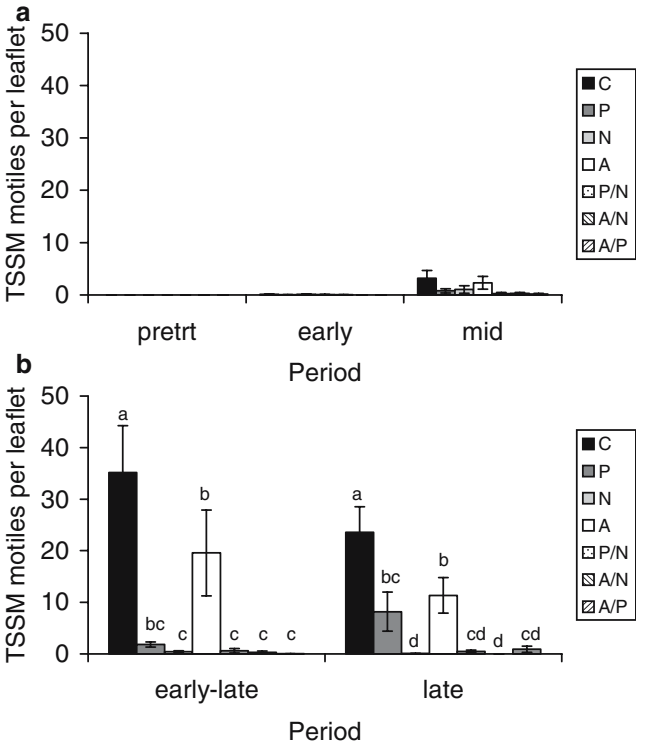

Fig. 3 Average TSSM motiles in (a) pretreatment, early and mid and (b) early-late and late periods of the 2004/2005 season. Treatments with the same letter are not significantly different from each other. Error bars represent standard error of the mean. (C = control, P = *P. persimilis*, N = *N. californicus*, A = Acramite, P/N = *P. persimilis*/*N. californicus*, A/N = Acramite/*N. californicus*, and A/P = Acramite/*P. persimilis*)

combination treatments ($F = 2.7$, df = 6,18, $P < 0.05$) (Fig. 4a). In the mid-season, there was a trend toward more TSSM motiles and eggs in the control compared to the *N. californicus*, *P. persimilis*/*N. californicus*, Acramite/*P. persimilis*, and Acramite/*N. californicus* treatments, but the differences were not statistically significant (motiles: $F = 2.1$, df = 6,18, $P = 0.10$; eggs: $F = 2.3$, df = 6,18, $P = 0.08$) (Figs. 3a, 4a). In the early-late season and late season, the control had significantly higher numbers of TSSM motiles and eggs than all of the other treatments except egg numbers in the Acramite treatment in the early-late season (early-late season: motiles: $F = 7.3$, df = 6,18, $P = 0.0004$; eggs: $F = 7.8 = 6,18$, $P < 0.0005$; late season: motiles: $F = 11.1$, df = 6,18, $P < 0.0001$; eggs: $F = 11.7$, df = 6,18, $P < 0.0005$) (Figs. 3b, 4b). In both periods, there were significantly more TSSM motiles and eggs in the Acramite treatment when compared with the *N. californicus*, *P. persimilis*/*N. californicus*, Acramite/*P. persimilis*, and Acramite/*N. californicus* treatments (Figs. 3b, 4b). During the early-late season, numbers in the *P. persimilis* treatment fell between those in the Acramite treatment and those in the other four treatments, but did not differ significantly from any of these treatments. In the late season, however, there were significantly fewer TSSM motiles in the *N. californicus* and Acramite/*N. californicus* treatments and significantly fewer TSSM eggs in the *N. californicus*,

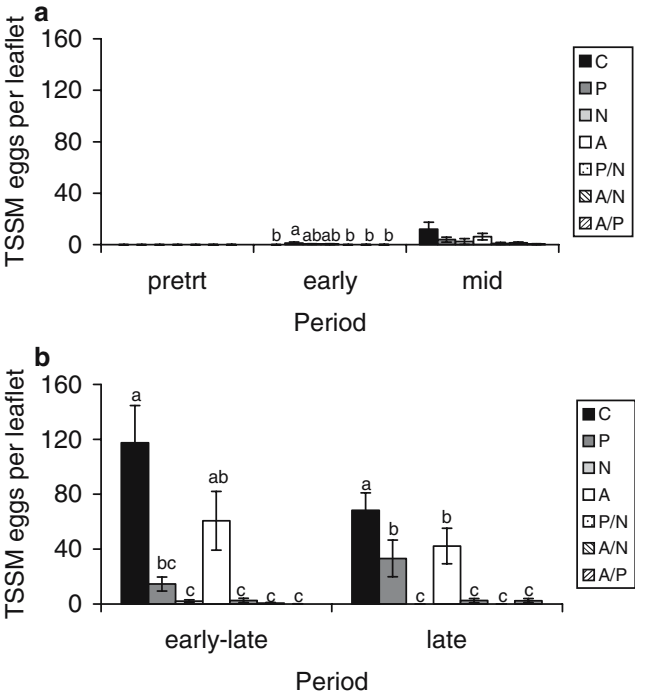

Fig. 4 Average TSSM eggs in (a) pretreatment, early and mid and (b) early-late and late periods of the 2004/2005 season. Treatments with the same letter are not significantly different from each other. Error bars represent standard error of the mean. (C = control, P = *P. persimilis*, N = *N. californicus*, A = Acramite, P/N = *P. persimilis*/*N. californicus*, A/N = Acramite/*N. californicus*, and A/P = Acramite/*P. persimilis*)

P. persimilis/*N. californicus*, Acramite/*P. persimilis*, and Acramite/*N. californicus* treatments compared with the *P. persimilis* treatment.

Predatory mites

Very few of either species of predatory mite were recorded from all treatments in the 2004–2005 field season. There were no significant differences between *P. persimilis* motile and egg populations among the *P. persimilis*, *P. persimilis*/*N. californicus*, and Acramite/*P. persimilis* treatments (motiles: $F = 1.8$, df = 2,171, $P = 0.17$; eggs: $F = 2.3$, df = 2,171, $P = 0.10$). There were also no significant differences between *N. californicus* motile and egg populations among the *N. californicus*, *P. persimilis*/*N. californicus*, and Acramite/*N. californicus* treatments (motiles: $F = 1.0$, df = 2,171, $P = 0.35$; eggs: $F = 0.90$, df = 2,171, $P = 0.41$).

Discussion

In the greenhouse, the *P. persimilis*/*N. californicus* combination treatment significantly reduced TSSM numbers. This strategy appears to be more effective than releasing *P. persimilis* alone and may be one option for long-term suppression of

TSSM. However, there were no significant differences between the *P. persimilis*/*N. californicus* and the *N. californicus* treatments. In the field, the *P. persimilis*/*N. californicus* combination treatment differed in its effectiveness between the two seasons. Although the combination treatment effectively reduced TSSM numbers in the 2003–2004 field season, it appeared to take longer than the single treatment of *N. californicus*. In the 2004–2005 field season, however, TSSM numbers remained low throughout the season in both of these treatments. Schausberger and Walzer (2001) found that treatments of either species alone or of both species in combination reduced the TSSM population to zero on gerbera plants in the greenhouse.

The numbers of predators in the single and combination treatments were not statistically different from each other for either predatory mite species in both the greenhouse experiment and the 2004–2005 field season experiment. This is most likely due to the fact that so few predators were found. In both experiments, the numbers of available prey were low resulting in low predatory mite populations. In the field, some predatory mites dispersed into other treatments. Some mites may have attempted to disperse in the greenhouse experiment. Both species may also have resorted to cannibalism in order to survive (Schausberger 2003; Schausberger and Croft 2000; Walzer and Schausberger 1999).

However, data from the 2003 to 2004 field season show that *P. persimilis* numbers were greatly reduced in the *P. persimilis*/*N. californicus* combination treatment while *N. californicus* numbers were apparently unaffected. Walzer et al. (2001) found that when *P. persimilis* and *N. californicus* were reared together on bean leaves with abundant prey, *N. californicus* eventually displaced *P. persimilis*. In our study, *N. californicus* may have displaced *P. persimilis* in the *P. persimilis*/*N. californicus* treatment. In the absence of spider mite prey, *N. californicus* adults and immatures prey more on heterospecifics than on conspecifics, whereas *P. persimilis* adults and larvae are more prone to cannabilism (Walzer and Schausberger 1999; Schausberger and Croft 2000). Also, *N. californicus* females produce eggs when feeding on heterospecifics but not when feeding on consepcifics. In contrast, *P. persimilis* females do not produce eggs after consuming either hetero- or conspecifics (Schausberger and Walzer 2001; Walzer and Schausberger 1999). In the greenhouse, *N. californicus* is more likely to resort to intaguild predation than *P. persimilis* (Schausberger and Walzer 2001). The combination of intraguild predation by *N. californicus*, cannibalism, and the inability to reproduce when consuming predatory mite prey may have led to the drastic difference in *P. persimilis* numbers between the single and combination treatments.

Although *N. californicus* appears to eventually displace *P. persimilis*, releasing the two in combination did significantly reduce TSSM numbers. *Phytoseiulus persimilis* is a specialist predatory mite that preferentially feeds on spider mites, mostly from the genus *Tetranychus* (McMurtry and Croft 1997). When given a choice, *N. californicus* prefers larval TSSM to larvae of either *Typhlodromus pyri* (Scheuten) or *T. montdorensis* (Schicha), two predatory mite species used in the UK (Hatherly 2005). Since both species prefer TSSM, releasing them together may be a viable treatment option especially for growers who do not want to use pesticides. *Neoseiulus californicus* could be introduced into the field early in the season, since it can survive at low prey densities, and then *P. persimilis* could be released if TSSM populations began to increase. Further research into this area is needed.

In the greenhouse, Acramite appears to be effective in controlling TSSM populations. However, the slight increase in TSSM numbers at 4 weeks suggests that it

does not kill 100% of the population and that its effects eventually decrease over time. In the 2004–2005 field season, Acramite application did not effectively control the high TSSM population that had built up by the time of the second application in the early-late season. Since it can only be sprayed twice in a season, timing of Acramite applications to when the TSSM population is beginning to approach threshold is critical, especially if it is the only mite control strategy employed.

The application of *N. californicus* or *P. persimilis* following Acramite sprays may be an important management strategy for TSSM control in Florida. During the 2004–2005 field season, both the Acramite/*N. californicus* and the Acramite/*P. persimilis* treatments appeared to have effectively controlled TSSM populations. Few predatory mites were found in these treatments. However, predatory mites were never found on leaves without TSSM or evidence of recent TSSM infestation. Ahn et al. (2004), Kim and Yoo 2002, Veire and Tirry (2003) and White (2004) report that Acramite showed low toxicity towards both *P. persimilis* and *N. californicus* in the laboratory. Therefore, the low numbers of predatory mites most likely reflected the low numbers of available prey rather than suppression resulting from the Acramite application. However, further research into the effects of Acarmite on *N. californicus*, *P. persimilis* and other predatory mite species in the field is needed to substantiate this hypothesis.

Two applications of Acramite or two releases of *N. californicus* can effectively control TSSM in north-central Florida. However, releasing *N. californicus* or *P. persimilis* after applying Acramite at half the recommended rate also appears to effectively control TSSM. This reduces the amount of miticide sprayed and costs less than using either predatory mite species alone. Using the two mite species in combination also appears to be a viable treatment option, but more research is needed to determine when to release both species. Our findings give growers several options for TSSM control that are effective and appear to have no significant impact on human health or the environment.

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