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Control of Broad Mites, Spider Mites, and Whiteflies using Predaceous Mites in Open-field Pepper and Eggplant

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Additional index words. *Amblyseius swirskii, Amblyseius cucumeris, Neoseiulus californicus, Polyphagotarsonemus latus, Bemisia, Tetranychus*

The broad mite *Polyphagotarsonemus latus* (Banks), the spider mites *Tetranychus urticae* (Koch) and *T. evansi* (Baker and Prichard), and the whitefly, *Bemisia tabaci* (Gennadius), are serious pests of pepper (*Capsicum annuum* L.) and eggplant (*Solanum melongena* L.) in Florida and elsewhere. In greenhouse vegetable production, *Amblyseius cucumeris* (Oudemans) is commonly used for broad mite and thrips control, *Neoseiulus californicus* (McGregor) for broad mites and spider mites, and *A. swirskii* Athias-Henriot for broad mite, whitefly, and thrips. However, there is little information on the use of these predaceous mites in open-field pepper and eggplant production in Florida. Activity of the predators *A. cucumeris* and *A. swirskii* was evaluated in eggplant and 'Serrano' pepper in experimental plots in southwestern Florida. Both mites provided significant levels of control of broad mite on both crops, although *A. swirskii* provided better control, required fewer releases, and also suppressed *B. tabaci*. Eggplant receiving *A. swirskii* yielded significantly more fruit than untreated plants or even eggplants receiving two acaricide sprays. A mixture of *N. californicus* with *A. swirskii* released in eggplant at planting persisted well into the crop cycle and suppressed all three pests.

Broad mite, *Polyphagotarsonemus latus* (Banks), spidermites (*Tetranychus* spp.), and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), are serious pests of pepper, eggplant, and many other crops. All these pests are well adapted to open-field environments in the tropics and subtropics and to greenhouses everywhere. Furthermore, broad mites use the whitefly for dispersal within and among crops by phoresy (Palevsky et al., 2001).

The predaceous mite *Amblyseius cucumeris* Oudemans has been shown to provide effective control of broad mite on greenhouse-grown pepper (Gerson and Weintraub, 2007; Weintraub et al., 2003). *A. swirskii* Athias-Henriot was shown to feed and develop on whiteflies (Nomikou et al., 2001) and to control *B. tabaci*, also on protected pepper crops (Calvo et al., 2006). *Neoseiulus californicus* (McGregor) has also been shown to be effective against broad mite (Jovicich et al., 2008) and has provided effective spider mite control on greenhouse pepper (Weintraub and Palevsky, 2008). However, there is little information to document the utility of these phytoseiid mites for control of these same pests in the open field or on other susceptible crops such as eggplant. Here we report results of experiments designed to evaluate control of *B tabaci*, *P. latus,* and *T. urticae* with predaceous mites in open field plantings of pepper and eggplant in Southwest Florida.

Materials and Methods

Predaceous mites. A bran mite, *Tyrophagus* sp., originally obtained from F. Pettit (The Land, Disney World, Orlando, FL), was used as a food source for *A. cucumeris*. Bran mites were reared on wheat bran obtained from a local feed store. Bran was first oven sterilized for 24 h at 75 °C in a 20-L covered polyethylene bucket. The rearing unit was a smaller bucket of 4-L capacity filled with 2 L sterilized bran. Five such buckets were maintained in an air-conditioned greenhouse sitting in pans of soapy water to prevent escape. Moisture was maintained by spraying the bran with 60 mL water while stirring constantly every 3 or 5 d at 27 ± 1 °C and relative humidity (RH) 60% ± 5%.

A. cucumeris was reared in three superimposed 2-L bucket containers stacked one upon the other. Bottoms of the upper and middle buckets were replaced by fine screen to permit mites to migrate downward through the buckets. A clean bucket with fresh bran was placed at the bottom each week, the top bucket was removed, and the contents of the remaining two buckets shifted upward. Buckets were held in trays filled with soapy water in an insectary maintained at 27 ± 1 °C, RH 60% ± 5%, 14:10 h L:D. Mites were monitored weekly under a stereoscopic microscope. Counts were also made by placing a known volume of bran + mites in dilute detergent, shaking with a Vortex mixer, allowing the mites to settle, and counting with a hemocytometer. The average obtained was 18 *A. cucumeris*/cm^3.

A. swirskii and *N. californicus* were provided by Koppert Biological Systems in Romulus, MI.

Field trials. Experiments were conducted at the University of Florida's Southwest Florida Research Center (SWFREC) in Immokalee. The first was designed to compare broad mite control on pepper obtained from *A. cucumeris* and *A. swirskii*. Seedlings of Serrano pepper 'Tuxtelo' were transplanted 17 Aug. 2006 into soil formed into three single-row beds covered with polyethylene film and drip irrigated. Beds were 73 m long on 1.8-m centers with 46 cm between plants within the row. A Latin square design was used with three treatments and three replications and plots

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of 40 plants each. Ten plants were removed between plots as a buffer. The first release was made on 27 Sept. by placing 5 cm^3 of substrate on each plant in separate plots designated for one or the other species. An estimated 90 *A. cucumeris* or 63 *A. swirskii* per plant were thus released. A single additional release of *A. swirskii* was made 2 weeks later, whereas *A. cucumeris* continued to be released at the same rate biweekly until the end of the experiment. Broad mite populations were monitored weekly from five leaves per plot randomly selected from the upper canopy. Plants were initially stripped of fruit to encourage growth but all fruit of marketable size were later harvested on 10 Dec.

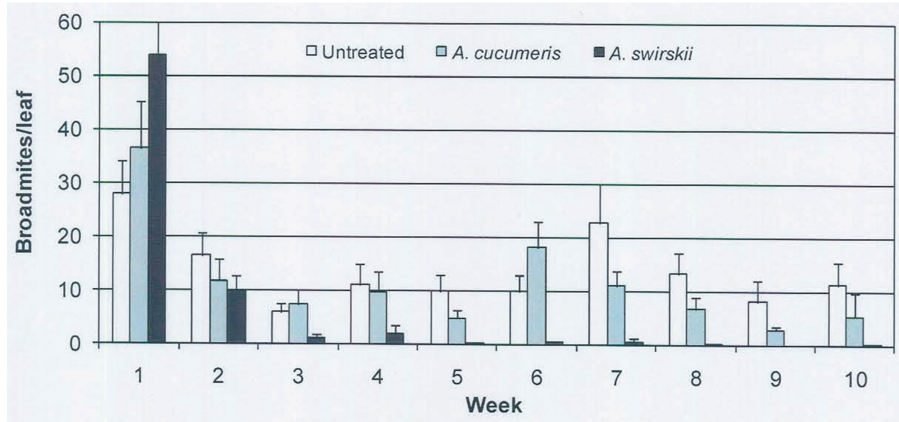

Fig. 1. Mean (+SE) number of broad mites (all stages) per upper leaf in response to releases of *A. cucumeris* and *A. swirskii* pepper, SWFREC, Sept.–Nov. 2006.

The second and third experiments on 'Serrano' pepper and 'Zebra' eggplant, respectively, at SWFREC were in Spring 2007 to compare suppression of both broad mite and whitefly with *A. swirskii* and spiromesifen (Oberon 2SC Bayer Crop Science, Research Triangle Park, NC). Plots were arranged in Latin square designs and consisted of 15 plants at 46-cm spacing with a 2.3 m of unplanted bed between plots for a plant population of 13,454/ha. One sachet of the commercial product Swirski–Mite Plus (Koppert Biological Systems, Romulus, MI), containing an estimated 250 predator mites, was released per plant 16 Mar. An additional application of 5 mL of Swirski–Mite containing an estimated 63 predators was made to each plant on 7 May. Oberon 2SC was applied twice as a foliar spray at 0.61 $L \cdot ha^{-1}$, 1 and 2 weeks later. A high-clearance sprayer was used operating at 200 lb per square inch and 2.3 miles per hour with the spray delivered through two vertical booms each fitted with four yellow hollow-cone nozzles (Albuz®) that applied 94 $L \cdot ha^{-1}$ each for a total of 748 $L \cdot ha^{-1}$.

One top pepper leaf was randomly selected from each of five pepper plants/plot, and an upper expanded leaf of five eggplant plants/plot were collected weekly and examined under a stereoscopic microscope. Eggs, nymphs, and adults of broad and predator mites were counted as well as eggs and nymphs of *B. tabaci*. Eggs, nymphs, and adults of the twospotted spidermite, *Tetranychus urticae* Koch, were counted in two additional samples taken as above from eggplants on 23 and 29 May.

Pepper fruit were not harvested due to losses from a heavy infestation of pepper weevil, *Anthonomus eugenii* Cano. All eggplant fruit of marketable size were harvested from five plants per plot on 16 May. Fruit were counted, weighed, and rated for broad mite damage as: 0 = no damage, 1 = slight discoloration of calyx, 2 = moderate russeting of calyx, 3 = severe russeting and pitting of calyx, and 4 = russeting on fruit.

A fourth experiment evaluated control of eggplant pests with releases of a mix of *A. swirskii* and *N. californicus* at 21 and 53 mites/plant, respectively. There were four treatments in a Latin square design with 15 plants per plot at 0.61 m between plants: mixture released 7 Oct. 2008 (same week of planting), 13 Nov. at first flowering, and 2 Dec. (first fruiting). Weekly sampling for both mites and whiteflies followed the same procedure as described above.

Analysis. Mite and whitefly counts were averaged over successive pairs of sample periods, multiplied over the number of intervening days and accumulated over the entire sample period to obtain mite × days, and whiteflies × days, respectively. These data and harvest results were subjected to analysis of variance and means separated by Fisher's LSD at $P < 0.05$ in the event of a significant treatment effect.

Results

***A. swirskii* vs. *A. cucumeris*.** The broad mite infestation was intense in this fall crop and the 'Serrano' peppers proved to be highly susceptible to injury. The most affected plants showed severe leaf distortion, russeting, and defoliation. The pre-release sample showed a mean 54 ± 8.9 broad mite eggs, nymphs, and adults in plots destined for release of *A. swirskii* compared to 36 ± 8.7 and 28 ± 6.1 on plants to receive *A. cucumeris* or nothing. Many fewer broad mite life stages were observed on plants receiving *A. swirskii* within 2 weeks of the first application and thenceforward (Fig. 1). Differences among accumulated post-release mite days were significant ($P < 0.0001$; $F = 31.7$; df = 6, 38), with most on untreated plants and fewest seen on plants receiving *A. swirskii* (Table 1). Thus, two releases of *A. swirskii* resulted in a 10-fold decrease in broad mite populations, while biweekly releases of *A. cucumeris* resulted in a lesser though still significant reduction of the pest compared to untreated plants.

Predaceous mites were not recovered from plants receiving *A. cucumeris* but were recovered at 0.2 ± 0.1 per leaf on 14 Nov. from plants receiving *A. swirskii* and at 0.7 ± 0.3 per leaf from untreated plants indicating that the mites were dispersing into areas of greater prey density. Whitefly numbers were low throughout the trial, with no significant reduction attributable to either predaceous mite. Nevertheless, yield effects were highly significant ($P < 0.0001$; $F = 21.1$; df = 6, 56) and greatest from plants treated with *A. swirskii*, least on untreated plants, and intermediate on

Table 1. Mean number of broad mite × days accumulated over 9 weeks following the first release of predatory mites, and weight of fruit harvested from 'Serrano' pepper plants in experimental plots during Fall 2006 at SWFREC in Immokalee, FL.

Treatment	Broad mite × days (no./leaf)	Fruit wt (g/plant)
Untreated	661 ± 54.5 a[z]	195 ± 18.8 c
A. cucumeris	484 ± 74.4 b	305 ± 25.3 b
A. swirskii	65 ± 16.5 c	422 ± 26.4 a

[z]Means followed by the same letter within the same column are not significantly different (LSD; $P \le 0.05$).

Table 2. Mean ± SE number of broad mite × days and whitefly × days accumulated over 7 weeks following the first release of *A. swirskii* in 'Serrano' pepper plants during Winter–Spring 2007 in experimental plots at SWFREC in Immokalee, FL.

Treatment	Broad mite × days (no./leaf)	Whitefly × days (no./leaf)
Untreated	111.5 ± 36.2 a[z]	33.6 ± 6.7 a
Oberon	74.0 ± 25.0 ab	21.2 ± 6.4 ab
A. swirskii	0.9 ± 0.7 b	13.5 ± 4.3 b

[z]Means followed by the same letter within the same column are not significantly different (LSD; $P \leq 0.05$)

plants treated with *A. cucumeris* (Table 1).

A. swirskii vs. spiromesifen—Pepper. Numbers of both broad mites and whiteflies were low in the pepper crop during this winter-spring season. Nevertheless, almost no broad mites and fewest whiteflies were observed on plants receiving *A. swirski* (Table 2).

A. swirskii vs. spiromesifen—Eggplant. Populations of both broad mites and whiteflies were greater on eggplant than on pepper. Predator mites were found in good number in plots receiving releases and persisted through 9 May, although at ever decreasing density after 9 Apr. (Fig. 2). A few predator mites were found on untreated plants, especially on 9 May, with even fewer observed on Oberon-treated plants.

Populations of broad mites were low but uniformly distributed over the plots when *A. swirskii* was released on 16 Mar. Numbers increased rapidly on untreated plants through 25 Apr. and more slowly on plants treated with spiromesifen (Fig. 3). However, virtually no broad mites were seen until 16 Apr. on plants receiving *A. swirskii* and only approached the other treatments during the last 2 weeks of the trial. Accumulated broad mite days were least on plants receiving *A. swirskii*, with no differences between the other two treatments (Table 3).

Whitefly populations were initially high in all plots, but fell precipitously on plants receiving *A. swirskii*, whereas they continued to increase on the remaining plants through 9 Apr. (Fig. 4). Significantly fewest whitefly days were accumulated on plants receiving *A. swirskii* and most on untreated plants, with intermediate numbers seen on sprayed plants (Table 3).

Spidermite numbers on eggplant were highly variable on 23 May with no significant differences ($P = 0.23$, $F = 2.8$, df = 4:44), albeit with a strong trend toward fewer on plants receiving *A. swirskii* (13.0 ± 4.0 per leaf) compared to untreated plants or those receiving Oberon (52.2 ± 21.2 and 45.1 ± 23.0, respectively). No such trend was observed on 29 May, nor were any *A. swirskii* observed on either of the two sample dates.

The greatest number and weight of fruit were harvested from eggplants upon which *A. swirskii* was released, and least on untreated plants (Table 3). Sprayed plants yielded intermediate amounts. Damage ratings were lower on plants receiving *A. swirskii* compared to the control or the miticide treatment.

Mixture of A. swirskii and N. californicus. Both predaceous mite species were found for over a month in eggplants receiving releases at planting, with *A. swirskii* persisting for at least a month and a half (Fig. 5). At that time the density of *A. swirskii* was the same on plants receiving the mites at planting or 2 weeks earlier at flowering, whereas no *N.californicus* were seen. Therefore, it appeared that *A. swirskii* persisted longer. However, whitefly numbers were reduced on plants receiving the mites for only 2 weeks after the first and second releases whereas spider mite and broad mite density was virtually zero on these plants through 8 weeks (Fig. 6).

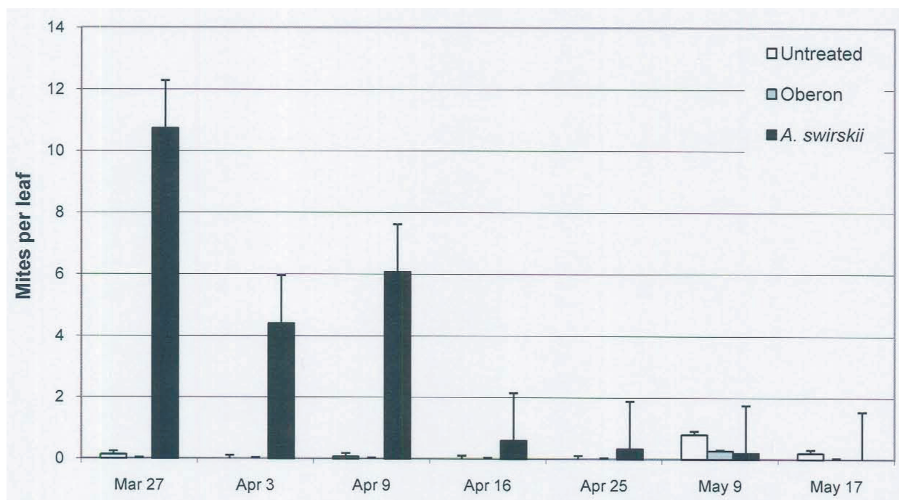

Fig. 2. Mean (+SE) number of *A. swirskii* mites (all stages) observed on eggplant leaves following release 16 Mar. 2007 and Oberon 2SC (spiromesifen 23.1%) applied twice as a foliar spray at 1.3 L·ha^{-1} 1 and 2 weeks later.

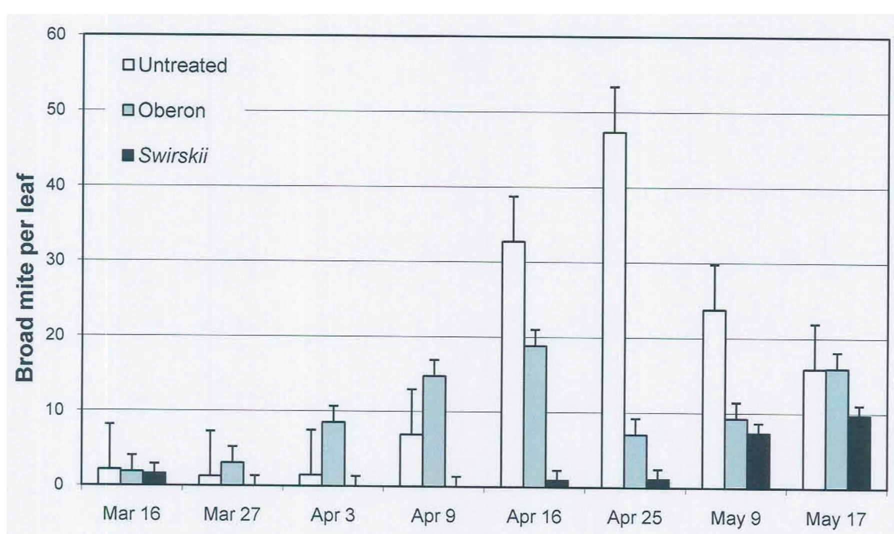

Fig. 3. Mean (+SE) number of broad mites (all stages) per leaf on eggplant at SWFREC in Spring 2007. *A. swirskii* released 16 Mar. and spiromesifen Oberon 2SC (spiromesifen, 23.1%) applied twice as a foliar spray at 1.3 L·ha^{-1} 1 and 2 weeks later.

Table 3. Mean ± SE number of broad mite × days, whitefly × days accumulated over 7 weeks during Winter–Spring 2007 following the first release of *A. swirskii* in 'Zebra' eggplants and fruit number and fruit weight harvested from five plants in experimental plots at SWFREC in Immokalee, FL.

			Fruit		
Treatment	Broad mites × days (no./leaf)	Whiteflies × days (no./leaf)	No.	Wt (kg)	Damage rating (0–4)
Untreated	1276.3 ± 229.2 a[z]	2341.0 ± 377.9 a	8.0 ± 1.2 c	3.9 ± 0.9 c	1.9 ± 0.2 a
Oberon	1005.0 ± 151.7 a	1604.2 ± 241.2 b	11.7 ± 3.7 b	6.0 ± 1.9 b	1.6 ± 0.6 a
A. swirskii	72.8 ± 12.9 b	211.8 ± 38.0 c	16.3 ± 3.3 a	8.8 ± 1.4 a	0.5 ± 0.3 b

[z]Means followed by the same letter within the same column are not significantly different (LSD; $P \leq 0.05$)

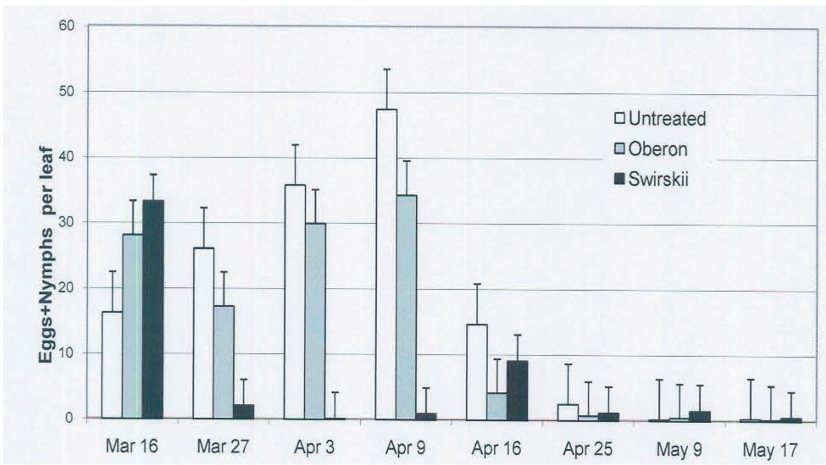

Fig. 4. Numbers *B. tabaci* (eggs + nymphs) per leaf on eggplant at SWFREC in Spring 2007. *A. swirskii* released 16 Mar. and Oberon 2SC (spiromesifen, 23.1%) applied twice as a foliar spray at 1.3 L·ha^{-1} 1 and 2 weeks later.

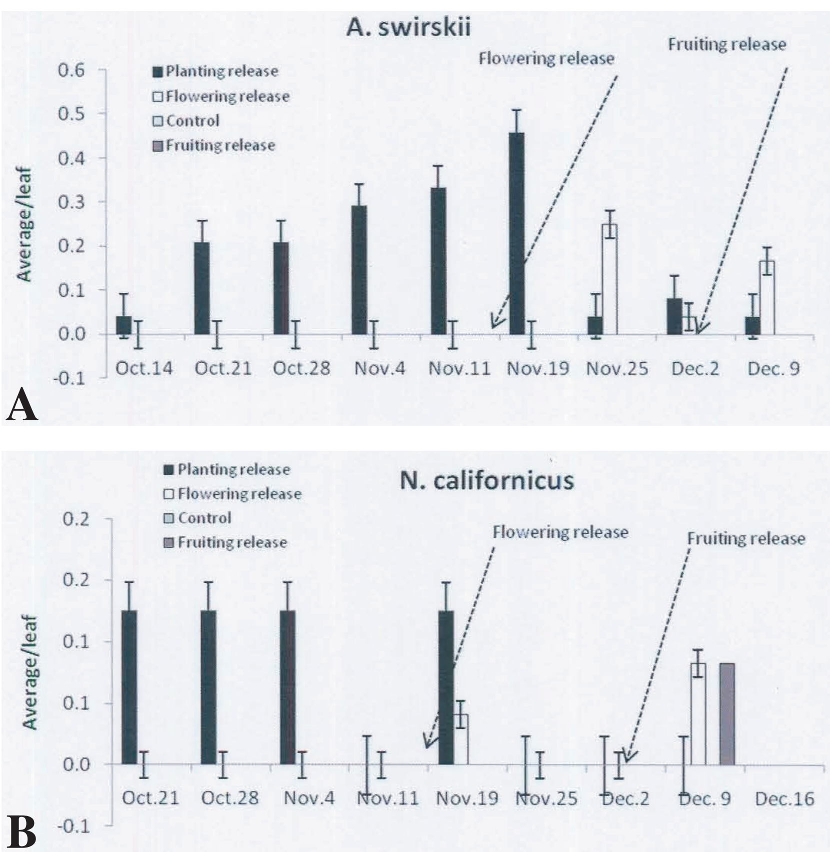

Fig. 5. Number of (**A**) *A. swirskii* or (**B**) *N. californicus* per leaf on eggplants receiving or not releases of an *A. swirskii* + *N. californicus* mixture, Fall 2008.

Discussion

Amblyseius cucumeris was able to exert significant control of broad mites, although many more applications were necessary to accomplish this than with *A. swirskii*. Even then, control was more effective with *A. swirskii*, due the ability of this mite to persist on the plants. Furthermore, excellent control of whiteflies on eggplant was observed with *A. swirskii* in the trial in 2007. Yields from plants on which *A. swirskii* was released were significantly increased on pepper in 2006 and eggplant in 2007, presumably in response to control of these pests.

Although *A. swirskii* provided satisfactory control of the broad mite and sweetpotato whitefly on eggplant, control of spidermites was not adequate. This shortcoming appeared to be aliviated by the addition of *N. californicus*, a predator of spidermites, that also controls broad mites (Jovicich et al, 2008). Furthermore, both predators provided excellent control of both mites for at least 8 weeks after an economical preventive release at planting. These excellent and encouraging results should stimulate extension agents and consultants to recommend biological control as a viable option for management of these pests in open-field fruiting vegetable production.

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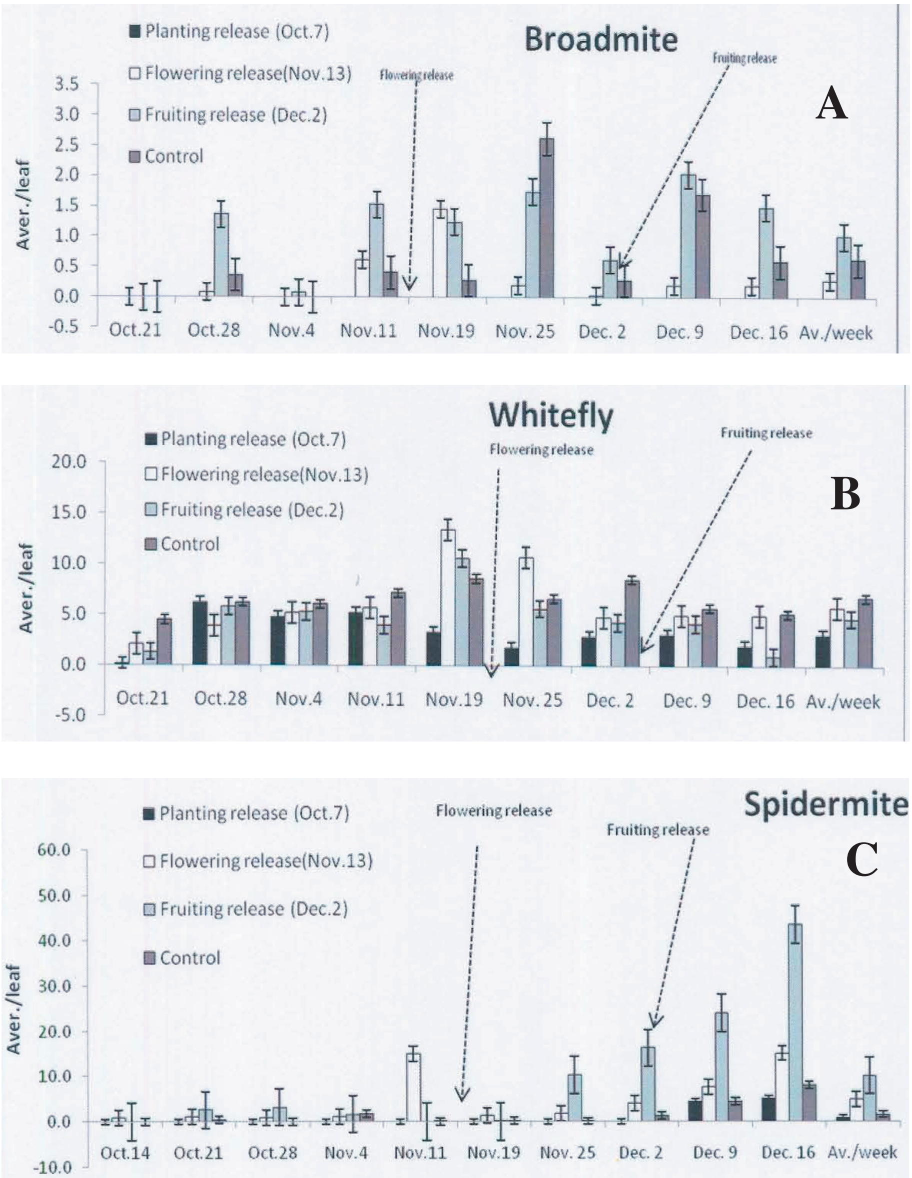

Fig. 6. Number of (**A**) whitefly immatures, (**B**) spider mites of any stage, or (**C**) broadmites of any stage per leaf on eggplants receiving or not releases of an *A. swirskii* + *N. californicus* mixture, Fall 2008.

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