BIOLOGICAL CONTROL OF WHITEFLIES AND WESTERN FLOWER THRIPS IN GREENHOUSE SWEET PEPPERS WITH THE PHYTOSEIID PREDATORY MITE *AMBLYSEIUS SWIRSKII* ATHIAS-HENRIOT (ACARI: PHYTOSEIIDAE)

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ABSTRACT

Currently, western flower thrips (*Frankliniella occidentalis*) is controlled in greenhouse sweet peppers with the phytoseiid predatory mite *Amblyseius cucumeris*, the anthocorid flower bug *Orius laevigatus* and the phytoseiid mite *Iphiseius degenerans*. Whiteflies (*Trialeurodes vaporariorum* and *Bemisia tabaci* are controlled by releasing parasitoids and mirid bugs (Miridae).

Cage trials and trials in commercial greenhouse crops with the phytoseiid predatory mite *Amblyseius swirskii* (Athias-Henriot, 1962) have shown a high efficacy against *Frankliniella occidentalis* and against *Bemisia tabaci* in sweet peppers. When the predatory mites were released preventively on flowering sweet pepper plants in a greenhouse in the Netherlands the establishment of *Amblyseius swirskii* was successful. In all trials *Amblyseius swirskii* has shown a very high numerical response to the presence of prey. Biological control of whiteflies with phytoseiid predatory mites, which can be economically reared in large quantities, might be a major step forwards for biological control in greenhouse crops, especially in areas with high whitefly and thrips populations such as Southern Europe.

INTRODUCTION

The greenhouse whitefly, *Trialeurodes vaporariorum*, and the tobacco whitefly, *Bemisia tabaci*, are major pests in greenhouse crops. In commercial greenhouses whiteflies are mainly controlled by releases of the parasitoids *Encarsia formosa* and *Eretmocerus eremicus* against *T. vaporariorum* and *Eretmocerus mundus* against *B. tabaci*. Whitefly parasitoids are not able to establish in a greenhouse when released preventively. Mirid bugs (Miridae) such as *Macrolophus caliginosus* Wagner are expensive and their use is limited to greenhouse tomatoes. Therefore, a biological control agent which is able to establish in a crop before whiteflies enter the greenhouse would be a supplement to the system.

Nomikou *et al.* (2003) showed that the phytoseiid mite *Amblyseius swirskii* (Athias-Henriot), predates on eggs and crawlers of *B. tabaci* and develops well on this prey. Since the late 1980's the predatory mites *Amblyseius cucumeris* is successfully used for control of Western Flower Thrips (*Frankliniella occidentalis*) in greenhouse cucumbers, sweet pepper, eggplants and a large range of greenhouse ornamentals. Although very effective in winter crops in greenhouses in Southern Europe *A. cucumeris* appears not very effective in summer crops. This might be caused by the high temperatures in combination with low humidity conditions during summer. *Iphiseius degenerans* is more adapted to the conditions of the Mediterranean and has proven to be an effective thrips predator in greenhouses in Northern Europe, but this predator is difficult to rear in large quantities. Messelink and Steenpaal (2003) and Messelink *et al.* (2005) showed that *A. swirskii* is a very effective predator of Western Flower Thrips in greenhouse cucumbers. Also in greenhouse trials against greenhouse whiteflies on cucumbers, excellent control was achieved (Messelink, pers. comm.). *A. swirskii* is a common predatory mite in the eastern part of the Mediterranean. The mites used in the following studies have been collected in Israel.

PREDATION AND OVIPOSITION RATE

Rates of predation and oviposition on a diet of thrips larvae were determined according to the method described by van Houten *et al.* 1995. Leave discs of cucumbers (4.5 cm^2) were placed upside down on pads of moist cotton wool, in a climate room at L16:D8, 25° C and 70% relative humidity. Single gravid female mites were placed on each leaf disc. The mites originated from cohorts of young nymphs of the same age which were reared on a diet of cattail pollen (*Typha latifolia*). At the start of the experiment the mites had been laying eggs for 2 days.All leave discs were infested with 12 first instar *F. occidentalis*. During four days the predators were transferred each day to fresh leave discs with 12 newly emerged thrips larvae. It was ascertained that the number of live prey never dropped below 6 per disc. Number mite eggs and killed thrips were assessed daily. Data of the first day were omitted from calculations of predation and oviposition rates. A total of eleven female predatory mites were assessed.

Using the same protocol, 10 gravid female predatory mites were assessed for there oviposition rate when fed with eggs of greenhouse whiteflies (*Trialeurodes vaporariorum*). Each day the predatory mites were transferred to fresh cucumber leaves with eggs of *T. vaporariorum*.

Table 1. Rates of predation and oviposition of *Amblyseius swirskii* on a diet of first instar *F. occidentalis* larvae and *T. vaporariorum* eggs, on cucumber leaf discs (4.5 cm^2 at 25°C and 70% r.h. Predation rate: mean number of larvae killed per female, per day. Ovipostion rate: mean number of eggs laid per female per day. N= number of predatory females; s.e= standard error.

Prey species	N	Predation rate (mean ± s.e.)	Oviposition rate (mean ± s.e.)
F. occidentalis	11	4.9 ± 0.3	2.1 ± 0.2
T. vaporariorum	10	-	2.3 ± 0.1

DIAPAUSE

Diapause experiments were performed according to the method described by van Houten *et al*. 1995. Predatory mites were reared on small plastic arena's (8 x 10 cm) placed on pads of moist cotton. A small roof (2 x 2 cm) made from a piece of transparent plastic was placed on the arena to provide shelter and as an oviposition site. The arena's were provided every second day with fresh cattail pollen and with purple pollen of the iceplant (*Mesembryanthemum* sp.). Iceplant pollen contains ^{2}-carotene. In the absence of ^{2}-carotene in their diet, some mite species do not respond to photoperiod or thermoperiod. Another advantage of the purple iceplant pollen is that egg production by individual non-diapausing females can easily be determined, as the white egg stands out clearly against the surrounding purple intestines. Pollen was provided by dusting it on the arena with a small brush. The colonies were kept in a climate room at 25°C, 70% relative humidity and L16:D8

A cohort of eggs, from 0-16 h after deposition was transferred to a new rearing unit in a climate cabinet under diapause inducing conditions of 19°C, 70% relative humidity and L10:D14. Once the eggs have hatched, 30 young females were carefully transferred to a unit identical to the rearing units and placed in a climate cabinet under diapause inducing conditions of 19°C, 70% relative humidity and L10:D14. It was ensured that ample males were present for insemination of the females. When no egg was seen in a female it was concluded that this female would not lay eggs and, hence, was in a state of reproductive diapause. The female mites with a visible egg were removed. If no egg was seen in a female within 3 days, the conclusion was that it had entered a reproductive diapause.

All 30 female mites were ovipositing. This proves that under the conditions of 19°C, 70% r.h. and L10:D14 this strain of *Amblyseius swirskii* is non-diapausing.

DROUGHT TOLERANCE

The influence of relative humidity on egg-hatching was examined in closed plastic boxes (18 x 14 x 9 cm) at 25°. Eggs from 0-16 h after deposition were transferred to small plastic arena's and floated on different supersaturated salt solutions. Three different relative humidities were obtained by using supersaturated salt solutions of Ca(NO3)2 (50.5% r.h.), KI (69% r.h.) and NaCl (75% r.h.) (Winston and Bates 1960).

Table 2. Egg survival of *Amblyseius swirskii* at different relative humidities at 25°C. N= number of eggs.

Salt solutions	Relative humidity	N	Eggs hatched
Ca(NO3)2	50.5%	154	3%
KI	69%	251	45%
NaCl	75%	160	84%

ESTABLISHMENT OF *AMBLYSEIUS SWIRSKII* IN SWEET PEPPERS

A field trial was conducted in a 7,000 m² commercial sweet pepper crop (var. Derby) in the Netherlands. The goal of this trial was to verify if *A. swirskii* is able to establish in a sweet pepper crop in the absence of prey with only plant pollen as food. When the trial started the plants were flowering, 80cm high and free from pests. *A. swirskii* was released in a plot of 1,500 m². The predatory mites were released in weeks 7 and 10 at a rate of 25 individuals per m² per release. Other natural enemies which were released in the entire greenhouse are: *Orius laevigatus*, *E. mundus*, *Phytoseiulus persimilis* and *Aphidius ervi*. Observations were done every other week. Per observation 50 leaves from the higher part of the plants and 25 flowers were chosen randomly. The number of *A. swirskii*, *B. tabaci* and *O. laevigatus* was assessed.

A. swirskii established well. On the leaves a population of 4 to 5 predatory mites (all stages together) per leaf was reached within 4 weeks and remained at that level until the end of the trial (Fig. 1). In the flowers the *A. swirskii* population reached a peak of 3 predatory mites per flower 10 weeks after the last introduction, but afterwards the population decreased, probably due to the presence of *O. laevigatus* in the flowers (Fig. 2).

The pest level remained low throughout the entire trial period. *F. occidentalis* was not observed at all and *B. tabaci* was found at a level of 1 or 2 individuals per 50 leaves. The only pest which was found frequently was *Tetranychus urticae* Koch at an incidence between 0 – 12% of the leaves.

Despite low pest levels, *A. swirskii* remained present on the plants throughout the season which indicates that *A. swirskii* can be released preventively in a sweet pepper crop. The establishment, speed of population development and persistence in the crop are much better than for *Amblyseius cucumeris*.

BIOLOGICAL CONTROL OF *BEMISIA TABACI* WITH *AMBLYSEIUS SWIRSKII*

A semi field trial was conducted in an 400 m2 experimental plastic tunnel in Aguilas, Spain starting at the end of May until the end of July. The plastic tunnel was divided by 50 mesh screens in 6 compartments of 8 m². 10 poorly flowering sweet pepper plants of 50cm height were planted in each compartment at the start of the trial. *A. swirskii* was released in 3 compartments while the other 3 remain untreated (3 replicates per treatment). *B. tabaci* was released in all compartments. The release schedule is shown in table 3.

To assess the *A. swirskii* and *B. tabaci* population, 3 leaves (top, middle and bottom) from 5 plants per compartment were randomly chosen and observed weekly. All stages of *A. swirskii* and *B. tabaci* were counted separately.

A. swirskii managed to keep the *B. tabaci* population low in all compartments where this predatory mite was released, while in the untreated compartments the *B. tabaci* population increased rapidly. (Fig. 3)

A. swirskii established in all 3 compartments where it was released. After some weeks the first *A. swirskii* was also found in the untreated control cages and the population increased very rapidly. (Fig. 4)

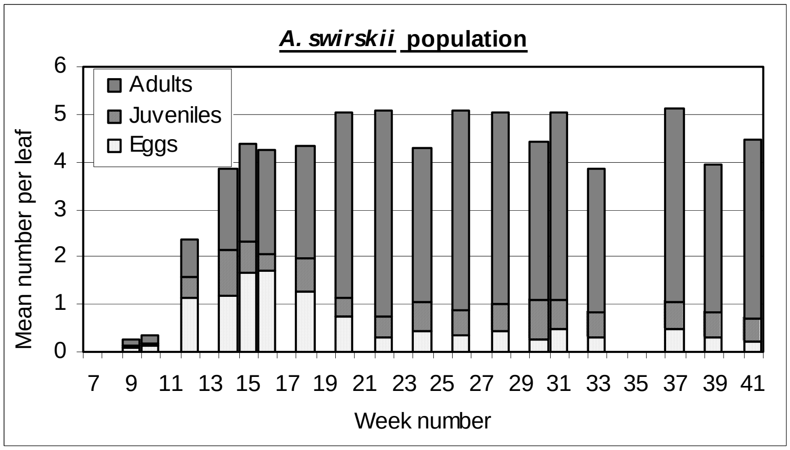

Figure 1. Mean number of *A. swirskii* per leaf. (n = 50).

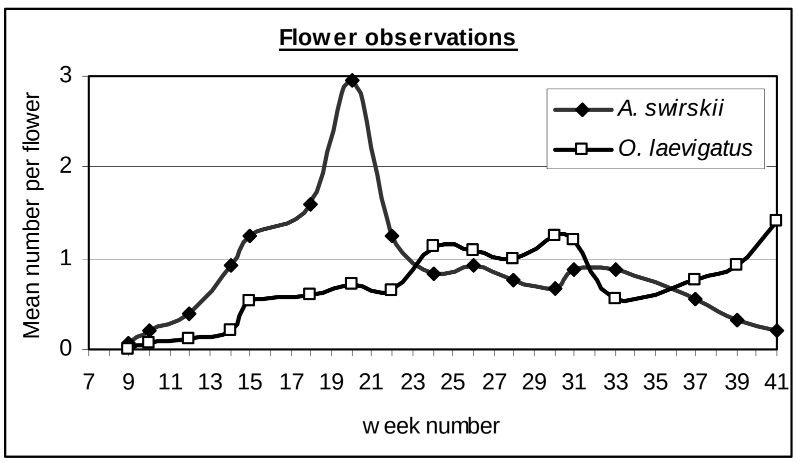

Figure 2. Mean number of *A. swirskii* and *O. laevigatus* per flower. (n = 25).

Table 3. Release schedule (number of adults released per plant) per treatment.

	Day 0		Day 6		Day 7		Day 14	
Treatment	*B.tab.**	*A.swi.**	*B. tab.*	*A. swi.*	*B. tab.*	*A. swi.*	*B. tab.*	*A. swi.*
A. swirskii	2	-	-	80	2	-	4	-
Untreated control	2	-	-	-	2	-	4	-

**B. tab.* = *B. tabaci* and *A. swi.* = *A. swirskii*.

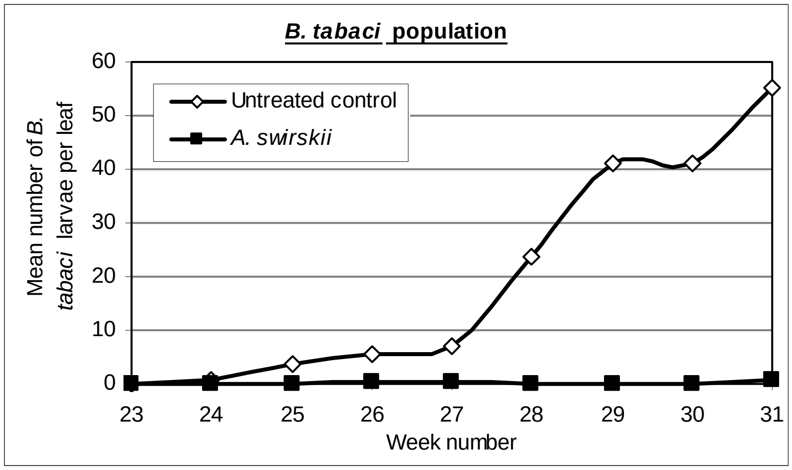

Figure 3. Mean number of *B. tabaci* larvae per leaf. Average of 15 leaves per compartment and 3 compartments per treatment.

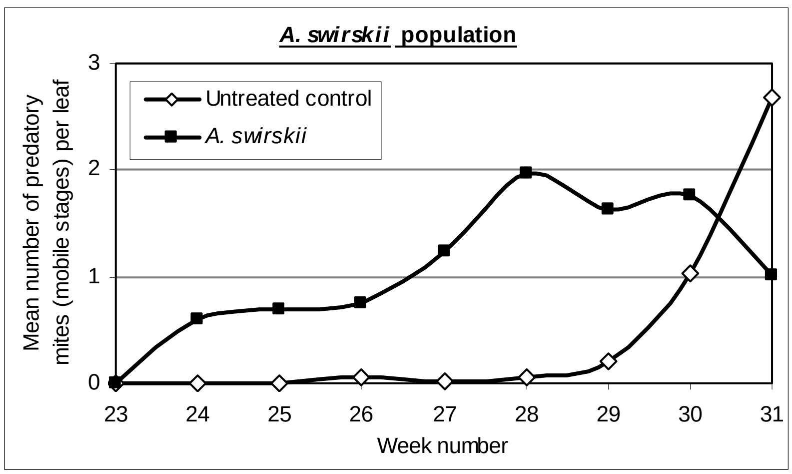

Figure 4. Mean number of *A. swirskii* (mobile stages) per leaf. Average of 15 leaves per compartment and 3 compartments per treatment.

COMPARISON OF FOUR PREDATORY MITE SPECIES AGAINST WESTERN FLOWER THRIPS

This experiment was carried out in 23 walk-in cages of 100 m^2, each cage having 1 row of 13 sweet pepper plants. When the plants had started to flower the western flower thrips and predatory mites were released in the numbers as shown in table 4. The trial was done in the summer period. The maximum day temperature was between 28-30°C with peaks up to 40°C. To monitor thrips and predator populations, samples of 30 leaves and 10 flowers were taken every week.

Iphiseius degenerans and *A. swirskii* established more successfully than *A. cucumeris* and *A. andersoni* (Fig. 5). *Iphiseius degenerans* performed best: the predator population increased rapidly and reached higher densities than *A. swirskii*, particularly in the flowers but also on the leaves,.

The thrips population in the flowers at the last counting is presented in figure 6. *Amblyseius swirskii* was most succesfull in thrips control, followed by *A. cucumeris* released by means of a slow-release breeding sachet, *I. degenerans, A, andersoni* and *A. cucumeris,* in descending order.

Table 4. Release rates of predatory mites and thrips in 23 different cages.

Predatory Mite Species	Release rate of predatory mites per plant in wk 24	Release rate of *F. occidentalis* per plant in wk 23, 24, 25, and 26 per cage	Number of Replicates
A. swirskii	30 females	(4 x) 2 females	4
A. andersoni	30 females	,,	4
A. cucumeris	30 females	,,	3
A. cucumeris	1 sachet	,,	4
I. degenerans	30 females	,,	4
Control	-	,,	4

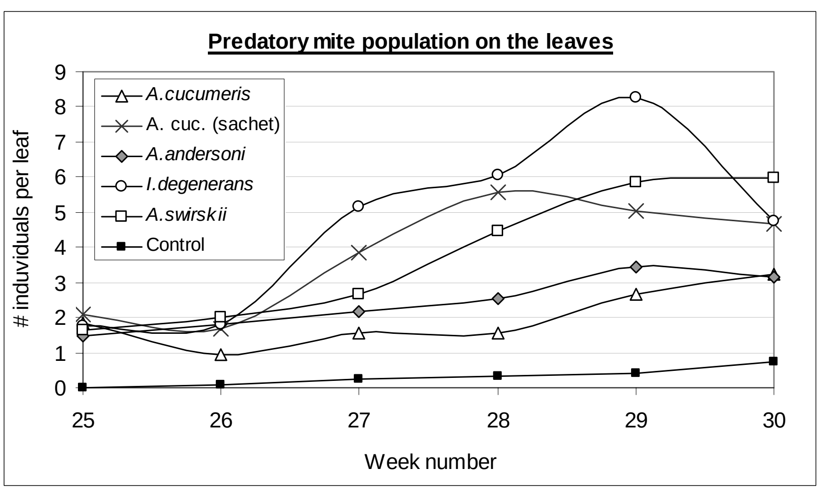

Figure 5. Population fluctuations of 4 predatory mite species on leaves of sweet pepper plants in 23 greenhouses.

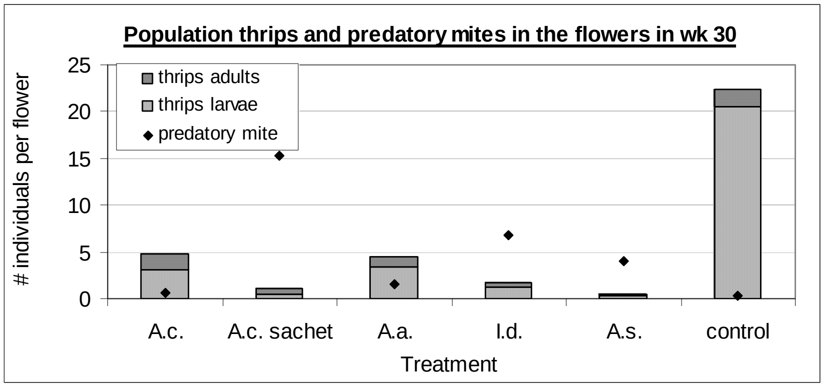

Figure 6. Mean numbers of *F. occidentalis* and 5 predatory mite species in flowers of sweet pepper plants in 23 greenhouses. Ac. = *A. cucumeris,* Aa. = *A. andersoni,* Id. = *I. degenerans,* As. = *A. swirskii* and Ac. sachet = a slow release sachet with *A. cucumeris.*

COMPARSION OF *A. SWIRSKII* AND *A. CUCUMERIS* FOR THRIPS CONTROL

This experiment was performed in 4 cages (3x1x2 m) in an experimental greenhouse. 5 flowering sweet pepper plants of 60 cm height were placed in each cage. Releases of 1 *A. swirskii* per leaf were compared with releasing either 1 *A. cucumeris* per leaf or 3 releases of 10 *A. cucumeris* per leaf at weekly interval. The latter treatment simulates the effect of using slow-release breeding sachets, which is standard practice when releasing *A. cucumeris.* To monitor western flower thrips and predator populations, 5 leaves and 1 flower per plant (25 leaves and 5 flowers per cage) were monitored every week from day 13 onwards.

The cage experiment showed that even when *A. swirskii* was released in dosage 30 times lower than *A. cucumeris,* the establishment of *A. swirskii* was better (Fig. 7). The impact of both predators on the thrips population at these release rates was comparable. Based on these results, *A. swirskii* can be regarded as a promising candidate for thrips control in sweet pepper.

Table 5. Release rates of predatory mites and western flower thrips in 4 different cages.

Predatory mite species	Release rate of predatory mites per cage (number/ leaf)	Release rate of *F. occidentalis* per cage
cage 1: *A. swirskii*	150 adults (1/leaf) on day 6	(3 x) 10 females (day 0, 7, 14)
cage 2: *A. cucumeris*	150 adults (1/ leaf) on day 6	,,
cage 3: *A. cucumeris*	3x 1500 adults (3x10/leaf) day 6, 13, 20	,,
cage 4: control	-	,,

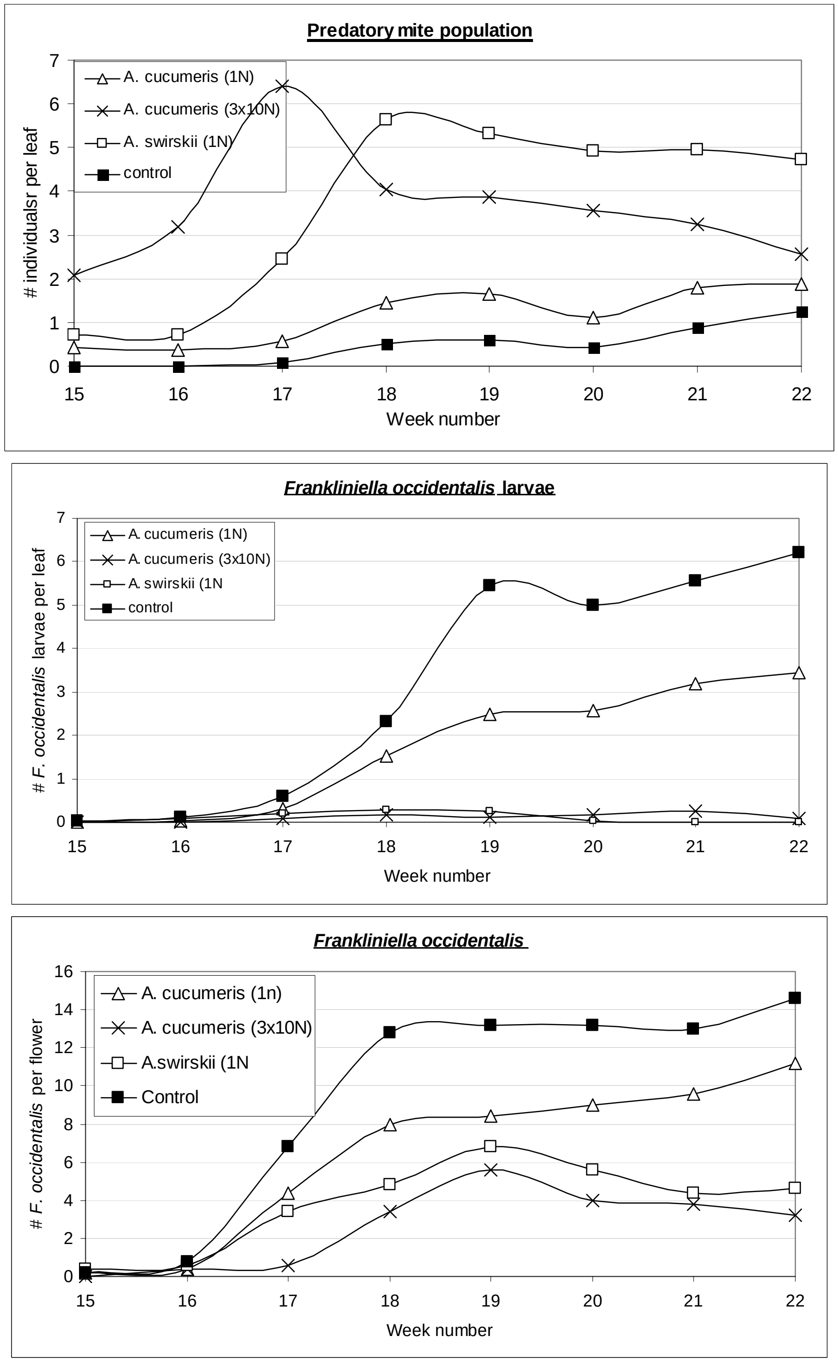

Figure 7. Population fluctuations of *Frankliniella occidentalis* and the phytoseiid mites, *Amblyseius cucumeris* and *A. swirskii,* on leaves and flowers of sweet pepper plants in 4 cages.

CONCLUSIONS

Amblyseius swirskii predates, reproduces and develops well on western flower thrips, greenhouse whiteflies and tobacco whiteflies. Under short day conditions of 19°C and L10:D14 this predatory mite is not sensitive to diapause. Draught tolerance of its eggs is similar to the draught tolerance of eggs of A. cucumeris with an RH_{50} around 70%.

A. swirskii is a promising control agent of whiteflies and western flower thrips on sweet pepper. Moreover, *A. swirskii* can be released preventively when the crop is flowering and remains present in the crop throughout the entire growing season, even while pests levels are very low. The establishment, speed of population development and persistence in the crop are much better than for *A. cucumeris*. Therefore *A. swirskii* may be a new solution for biological control of western flower thrips and of tobacco whitefly in sweet pepper in Northern and Southern Europe. *A. swirskii* is expected to replace *Iphiseius degenerans* and *A. cucumeris* in the future.

Because the biological control system for sweet peppers can be simplified and its robustness greatly enhanced by using this highly efficient predatory mite, *A. swirskii* is expected to become one of the keys to successful development of biological control in sweet peppers in areas with high pest pressures of thrips and whiteflies.

A. swirskii may be a new solution for biological control of both pests in sweet pepper in Northern and Southern Europe. A mass rearing technique for *A. swirskii* has already been developed.

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