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Orius albidipennis (Rueter) as an effective biocontrol agent against *Tetranychus urticae* Koch on pepper crops in greenhouse in Egypt

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Abstract

The present study was carried out in greenhouses, on sweet pepper crops, during the winter plantations 2015–2016 and 2016–2017 in a commercial farm located at Berkash district, Giza, Egypt. During the first season, three acariphagous biocontrol agent species, the predatory mite, *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) (at a rate of 2 individuals/m^2), and two of predatory insect, *Macrolophus caliginosus* Wagner (at a rate of 1 individual/m^2) and *Orius albidipennis* (Reuter) (at a rate of 1/2 individual adults/m^2), were applied to control *Tetranychus urticae*. The obtained results showed that *T. urticae* was controlled successfully using *A. swirskii* and *O. albidipennis*. Releasing of *A. swirskii* and *O. albidipennis* caused 26 and 24% yield increases, respectively, as compared to control treatment. During the second season of 2016–2017, the efficiency of *O. albidipennis* at a rate of 1/2 per m^2 was compared to three recommended pesticides, for controlling *T. urticae*. The obtained results revealed that applying *O. albidipennis* proved to be the most efficient control method against *T. urticae* on sweet pepper, with the lowest remaining pest density of *T. urticae* (2.9 mites/leaf); while with chemical control, the remaining density of *T. urticae* reached 20.13 mites/leaf at the end of the season. Thus, results demonstrated that the released insect predator, *O. albidipennis*, was the most effective method to control *T. urticae* under greenhouse conditions for two reasons. On the one hand, it resulted in a 31.36% yield increase, and on the other hand, it could reduce the chemical application, to improve food safety and environmental pollution reduction.

Keywords: Biological control, Chemical control, Spider mites, *Amblyseius swirskii*, *Macrolophus caliginosus*, *Orius albidipennis*

Background

The sweet pepper, *Capsicum annuum* L., is one of the most important vegetable crops. In Egypt, it is cultivated for local consumption and exportation (El-Laithy et al. 2013). It covers a production area of about a quarter million m^2 in greenhouses and yielded 9993 tons in 2013 (Heikal and Ebrahim 2013). The two spotted spider mite, *Tetranychus urticae* Koch, is a ubiquitous and economically important agricultural pest feeding on a wide range of host plant species (Xie et al. 2006). Probably, the most important pest species in the family is Tetranychidae (Tehri et al. 2014) and it is known to attack about 1200 species of plants. The economic threshold for spider mites was estimated as three or more motile forms per leaf (Warabieda 2015). Under favorable conditions, spider mites can rapidly build up to very large populations where they are characterized by a high reproductive capacity, causing important economic damage and yield losses close to 90% (Ginette et al. 2014).

Chemical control is the most common strategy for controlling *T. urticae*. However, this strategy is hindered by the development of population resistance to acaricides. Moreover, pesticide residues build up in leaves. Thus, the option of applying biological control against *T. urticae* has been considered, since it is a way to solve the prior mentioned problems. Among

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the natural enemies of *T. urticae*, *Orius* spp. have shown promising control capacities and thus interest for their use as one of the biological control agents. *Orius albidipennis* is the commonest *Orius* species in Mediterranean countries (Al-Kherb 2013), which led us to choose it in the present study.

Amblyseius swirskii Athias-Henriot is one of the most important generalist indigenous predators of tetranychid mites (Fatnassi et al. 2015). This mite is a polyphagous predator capable of preying on a number of food items, including spider mites (Van Houten et al. 2007), whiteflies (Hoogerbrugge et al. 2005; Calvo et al. 2006), and thrips (Van Houten et al. 2005).

As well, *Macrolophus* bugs have been successfully used in temperate and Mediterranean Europe for augmentative biological control in protected cultivation. Although mainly marketed for controlling whitefly pests, they are polyphagous and also feed on several other arthropod pests. *Macrolophus caliginosus* Wagner (Heteroptera: Miridae) has proven to be effective in controlling many insect pests of greenhouse vegetables (Kortam et al. 2014).

The present study aimed to evaluate the efficacy of *O. albidipennis* compared to other biocontrol agents and also to chemical application for controlling *T. urticae* on sweet pepper under greenhouse conditions in Egypt.

Materials and methods

The hangable cards of *A. swirskii* were provided by the INRA Research Center in Sophia Antipolis, France, within the framework of the Imhotep project "Characterization and modeling of microclimatic heterogeneity at the plant level, in relation to the repartition of biocontrol agents (*Neoseiulus cucumeris* and *A. swirskii*) used to control thrips and red spider mites on greenhouse crops". *O. albidipennis* and *M. caliginosus* have been reared at "*Chrysopa* mass rearing unit" at the Faculty of Agriculture, Cairo University, Giza, Egypt.

Rearing of *Orius albidipennis*

Adults of *O. albidipennis* were placed in jars (12 cm in height and 7 cm in diameter) and provided with fresh bean pods (*Phaseolus vulgaris*) for oviposition. *Ephestia kuehniella* eggs were introduced as a food source. The pods were collected daily and placed in boxes measuring (16 L× 25 W × 11 H (cm)) until hatching for nymphal rearing. After hatching, *E. kuehniella* eggs were also used as a food source for nymphal rearing. The rearing of *O. albidipennis* was carried out in a controlled climatic room at a temperature of 24.3 ± 0.2 °C, photoperiod of 16 h lighting per day, and a RH of 58.0 ± 0.5%.

Rearing of *Macrolophus caliginosus*

Rearing was carried out in Plexiglass cages (45 L × 45 W × 45 H cm) kept at constant environmental conditions (25 ± 1 °C, 70 ± 10% RH and LD 16:8 photoperiod). Adults and nymphs of the predator were fed on UV-irradiated *E. kuehniella* eggs. Potato seedlings were used for egg laying: females deposited their eggs in the veins and the stakes of the leaf blade.

Experiments on sweet pepper crops grown in a greenhouse

This study was carried out in a (4.5 m high) commercial greenhouse of 14,040 m^2 (180 L × 78 W m^2) located at Berkash (Giza, Egypt), during the fall-winter pepper plantation of the growing season, 2015–2016. Within this greenhouse, four 320 m^2 tunnels (40 L × 8 W m^2) were designed by installing plastic partitions and hermetically fixed to the greenhouse structure; this allowed the isolation of the tunnels from each other and avoided insects to pass from one tunnel to another.

Each tunnel, which was considered as a replicate, included four rows of 90 sweet pepper plants (*Capsicum annuum* L.) of the variety Helenscy (a total of 360 plants/tunnel). Fifteen-centimeter high sweet pepper plants were transplanted directly in the soil during the late summer (the 3rd week of August). The agronomic practices were carried out by farmers. Insecticide applications and plant pruning were strictly avoided during the experimentations. Three fungicide applications (commercial formulations: Acrobat/Copper 46% WP, Basf, Egypt; with application rate of 150 g hl^{-1}) were carried out at 20-day intervals during November.

An air temperature and relative humidity sensor (SEN-R Combisensor Temp/RH Adcon) was connected to a solar-powered data logger (A723 addIT, ADCON, Klosterneuburg, Austria). It was installed 1.5 m above the ground, in the central tunnel. Hygro-thermal data were recorded every 30 min throughout the experiment.

Releases of the different predators and samplings

Four previously described tunnels were used as follows: the first one for releasing *A. swirskii* at a rate of 2 adults/m^2, the second one for releasing *O. albidipennis* at a rate of 1/2/m^2, the third tunnel for *M. caliginosus* being released at a rate of 1 adult/m^2 (release dose of *M. caliginosus* was chosen according to Koskula et al. (1999)), while the fourth one remained untreated as a control. Nine releases were carried out during the season, at 10–15-day intervals, starting from December 2015 till March 2016. A total of 120 plants (30 plants/treatment) was chosen. Randomized samples of five leaflets/each plant were taken at 10–15-day intervals. Counts of moving stages of *T. urticae* were estimated in the field using a special magnifying hand lens (× 10).

Sweet pepper production yield was estimated for each treatment after releasing the three predators during winter plantation of 2015–2016 and 2016–2017.

A cost-benefit economical evaluation of the results, when applying the three released predators on the greenhouse sweet peppers to control *T. urticae*, was carried out. Cost benefits were calculated as follows (Goda et al. 2015):

$$\text{Cost benefits} = \text{costs of yield production} - \text{control costs.}$$

In the second season of plantation (2016–2017), the efficiency of *O. albidipennis* was compared to that of three recommended pesticides. Ten releases of the insect predator *O. albidipennis*, at the rate of $1/2/m^2$, were conducted during the season in a parallel experiment, using the three pesticides, Vertimec (abamectin), Kanemite (acequinocyl), and Agremic (abamectin), 12 times at the recommended dose (Table 1).

Statistical analysis

A randomized complete block design with two factors was used for analysis of all data with 30 replications for each parameter. The treatment means were compared by least significant difference (LSD) test as given by Snedecor and Cochran (1976) using Assistant program.

Results and discussion

In the early releases of the three investigated predators on the sweet pepper plants, the two-spotted spider mite populations were at their lowest density on the day of the predator release (Fig. 1). There were 3.5 motile stages/leaflet among the experimental tunnels. After the date of released predators, *T. urticae* populations slightly increased on sweet pepper plants received *O. albidipennis* and *A. swirskii* to reach their high density at February 16, 2016 (the 7th release of predators). There were 6.14 and 5.94 motile stages/leaflet in tunnels released with *O. albidipennis* and *A. swirskii*, respectively. Then, the mite populations slightly decreased in the previous tunnels to reach 2.8 and 2 motile stages/leaflet in the two released tunnels, respectively. However, these levels of mite infestation are known to be less injurious to plants and are considered within the economic threshold level (Warabieda 2015). For *M. caliginosus* released on the sweet pepper plants, similar trends of the two-spotted spider mite populations were observed until February 16, 2016 (the 7th week of predator release); then, that of the mite gradually increased to reach its maximum counts of 12.56 motile stages/leaflet on March 27, 2017. On the other hand, *T. urticae* populations increased gradually on sweet pepper plants in the control (untreated plants) tunnels. Then, the mite population increased rapidly to reach its maximum counts, i.e., 40.93 motile stages/leaflet on March 27, 2017.

Analysis of results showed that the time ($F = 35.91$; $P < 0.0001$) and type of released predators ($F = 183.24$; $P < 0.0001$) significantly affected the number of mites. The interaction treatment-date was also significant $F = 12.62$; $P < 0.0001$. All used predators (*O. albidipennis*, *M. caliginosus*, and *A. swirskii*) effectively reduced the number of *T. urticae* on sweet pepper plants. On March 27, 2016, the mean numbers of the two-spotted spider mite in all released tunnels were significantly lower than those in the control treatment (Fig. 1). The differences among treatments were highly significant $F = 204.283$; $P < 0.0001$.

A. swirskii treatment

Obtained results revealed that it is possible to reduce the number of *T. urticae* by applying biocontrol agents. In particular, the best results were obtained in the tunnels when the mite predator *A. swirskii* was released. The mean number of mites observed at *A. swirskii*

Table 1 A list of pesticide application used to control *T. urticae* on sweet pepper in greenhouse using a chemical treatment during winter plantation of 2016–2017

Date	Trade name	Active ingredient	Rates of application (cm^3/L)
21/11/2016	Vertimec 1.8%	Abamectin	200 cm^3/200 L
05/12/2016	Kanemite 15%Sc	Acequinocyl	200 cm^3/200 L
25/12/2016	Vertimec 1.8%	Abamectin	200 cm^3/200 L
16/01/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L
25/01/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L
05/02/2017	Agremic 8.4%Sc	Abamectin	40 cm^3/200 L
12/02/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L
22/02/2017	Kanemite 15%Sc	Acequinocyl	175 cm^3/200 L
28/02/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L
05/03/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L
10/03/2017	Kanemite 15%Sc	Acequinocyl	175 cm^3/200 L
17/03/2017	Vertimec 1.8%	Abamectin	200 cm^3/200 L

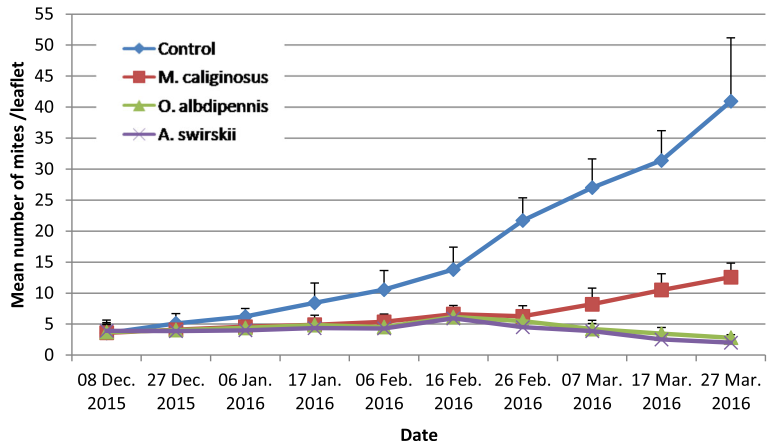

Fig. 1 Mean numbers of *T. urticae*/leaflet after releasing three different predators (*O. albidipennis*, *M. caliginosus*, and *A. swirskii*) on the sweet pepper in the greenhouse during the winter plantation of 2015–2016

treatments (2 mites/leaflet) remained lower than when releasing *O. albidipennis* and *M. caliginosus* (2.8 and 12.56 mites/leaflet, respectively).However, there was a significant difference between *O. albidipennis* and *M. caliginosus* ($F = 222.377$; $P < 0.0001$). These results were in agreement with Tomczyk and Andryka (2016) who observed that *A. swirskii* played a significant role in controlling populations of *T. urticae*.

O. albidipennis treatment

O. albidipennis proved to be highly efficient in controlling *T. urticae* on sweet pepper under greenhouse conditions. Mean number of *T. urticae* with *O. albidipennis* (2.8 mites/leaflet) was lower than with *M. caliginosus* (12.56 mites/leaflet) with a significant difference between both of their treatments ($F = 154.308$; $P < 0.0001$). However, insignificant difference between *O. albidipennis* and *A. swirskii* could be observed. Fathi (2014) reported that using *Orius minutus* led to effective and more sustainable management of *T. urticae* in potato fields.

M. caliginosus treatment

There was a significant difference between each of *M. caliginosus*, *O. albidipennis*, and *A. swirskii* treatments. The highest mean number of *T. urticae* after control treatment was recorded in *M. caliginosus* treatment (12.56 mites/leaflet), whereas it dropped to 2.8 and 2 mites/leaflet in the case of revealed *O. albidipennis* and *A. swirskii*, respectively. Moreover, it was of interest to mention that a high predation rate of *M. caliginosus* to *T. urticae* was obtained in the absence of greenhouse whitefly larvae (Veire et al. 2002).

The results of the present study showed the efficacy of *O. albidipennis* and *A. swirskii* in minimizing the damage levels of *T. urticae*, keeping thus the population density under an acceptable threshold, when compared to the untreated control plants.

Estimation of sweet pepper yield after releasing the three predators during winter plantation of 2015–2016

Production yield, in the experimental tunnels of the sweet pepper, was recorded during the winter plantation of 2015–2016. Sweet pepper plants protected by releasing *A. swirskii* yielded 881.22 kg, followed by those protected by *O. albidipennis* and *M. caliginosus* which produced 870.52 and 842.35 kg, respectively (Table 2), whereas it dropped to 685.2 kg in the unprotected plants, on which no predators were released. The obtained results showed that the production yield of sweet pepper in tunnels increased between 26 and 24% after releasing *A. swirskii* and *O. albidipennis*, respectively, as compared to control. These results confirm those obtained by Adly (2015) who reported that there was

Table 2 Total production yield, bioagent costs, and cost benefits of sweet pepper when releasing the three predators, *O. albidipennis*, *M. caliginosus*, and *A. swirskii*, in the experimental tunnels during winter plantation of 2015–2016

Treatments	Yield (kg)	Production price (LE)	Bioagent costs (LE)	Cost benefits (LE)
Control	685.2	8565	–	8565
O. albidipennis	870.52	10,881.5	129.6	10,751.9
M. caliginosus	842.35	10,529.375	259.2	10,270.175
A. swirskii	881.22	11,015.25	345.6	10,669.65

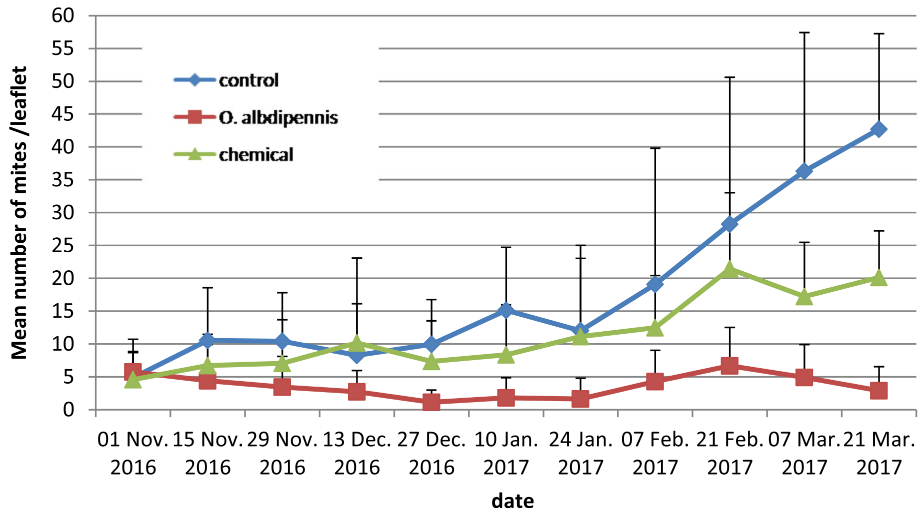

Fig. 2 Mean numbers of *T. urticae*/leaflet when controlled by two different (releasing predators and chemical pesticides) methods in a sweet pepper greenhouse during the winter plantation of 2016–2017

40% increase in pepper yield by using the mite predator as one of the biocontrol agents for controlling *T. urticae*.

Cost benefits when releasing the three predators of O. albidipennis, M. caliginosus, and A. swirskii

Data shown in Table 2 presented the cost benefits of each predator treatment. Releasing of *O. albidipennis* resulted in high cost benefits (10,751.9 LE) where the total cost of releasing *O. albidipennis* throughout the whole growing season attained is 129 LE, while that of *M. caliginosus* recorded the lowest cost benefit (10,270.175 LE). The cost benefits of *O. albidipennis*, *M. caliginosus*, and *A. swirskii* were more than control by 25.53, 15.85, and 20.49%, respectively.

The results showed the efficacy of *O. albidipennis* and *A. swirskii* in eliminating the damage levels of *T. urticae* and thus keeping the population density under an acceptable economic threshold.

Season 2016–2017

Figure 2 presents the mean number of *T. urticae*/leaflet for the three treatments. Analysis of treatment factors showed a high significant difference between these treatments ($F = 130.224$; $P < 0.0001$). Obtained results revealed that applying *O. albidipennis* proved to be efficient in controlling *T. urticae* on sweet pepper, with the lowest number of *T. urticae* recorded (2.9 mites/leaflet). However, with chemical control, the mean number of *T. urticae* varied from 12.48 mites/leaflet on the 7th of February to 20.13 mites/leaflet on the 21st of March (the end of the season). Moreover, development for resistance was observed in the *T. urticae* population, after application of pesticides (Hussey 1985).

Our strategy to control *T. urticae* achieved a good result since the pest population density could be kept below the economic threshold which has been estimated to be three motile forms per leaf (Warabieda 2015).

Estimation of sweet pepper yield after releasing *O. albidipennis* during winter plantation of 2016–2017

The highest yield production of sweet pepper (864.57 kg with a 31.36% increase) was recorded during the winter plantation in 2016–2017 when releasing *O. albidipennis*, when compared to that of the control, followed by that of the chemical treatment (754.7 kg) which represented 12.7% reduction in production yield, compared to that of *O. albidipennis* treatment. High population density of *T. urticae* in chemical treatment played a significant role in reduction of sweet pepper yield. Our results agree with those obtained by Edwards (1986) who found 60–80% reduction in yield by using pesticides to control spider mites and 23% increase in crop yield

Table 3 Total yield production, bioagent costs, and cost benefits of sweet pepper with release of *O. albidipennis* compared to chemical applications in the experimental tunnels during winter plantation of 2016–2017

Treatments	Yield/treatment (kg)	Production price (LE)	Bioagent costs (LE)	Cost benefits (LE)
Control	593.36	7417	–	7417
O. albidipennis	864.57	10,807.125	144	10,663.125
Chemical	754.7	9433.75	674.9	8758.85

in the case of biological control treatments in tomato and cucumber greenhouses.

Cost benefits in releasing O. albidipennis compared to applying chemical pesticides

The cost for all agricultural practices was equal in all experimental tunnels, except for the cost of *T. urticae* control. Ten releases of *O. albidipennis* throughout the whole growing season were attained (144 LE), which resulted the highest cost benefits (Table 3). The cost benefits of *O. albidipennis* treatment were more than those of the control by 43.67%. Twelve applications of recommended pesticides amounted to 674.9 LE.

Conclusions

In conclusion, *T. urticae* was able to cause significant damage to sweet pepper crop. Biological control using the insect predator *O. albidipennis* was the most effective method to control *T. urticae* under greenhouse conditions. On the one hand, it resulted in 31.36% increase in yield, and on the other hand, it could reduce the chemical application which would improve the food safety and reduce the environmental pollution.

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Authors' contributions

Field Application was carried out by MNK. SAEA performed the design of the study. SAEA, AIA and IHH revised the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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