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Research Article

Evaluation of *Chrysoperla carnea* and *Macrolophus pygmaeus* as biological control agents of *Frankliniella occidentalis* on Batavia lettuce under hydroponic cultivation

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Abstract: Few studies have investigated the efficacy of natural enemies against pests in hydroponic farming. We aimed to determine the effectiveness of two predators *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), and *Macrolophus pygmaeus* Rambur (Hemiptera: Miridae), for controlling *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in hydroponic cultures of Batavia lettuce. Both *C. carnea* and *M. pygmaeus* were released weekly with spot treatment: 10-20 individuals /m^2 and 0.25-5 individuals/ m^2/release, respectively. One of the more substantial conclusions from our current study is that *C. carnea* and *M. pygmaeus* highly reduced the *F. occidentalis* larvae and adults (45.85 and 60.91%) over the control treatments. The efficiency of *M. pygmaeus* was higher than that of *C. carnea*. The population of *F. occidentalis* decreased from 8.75, 7.75, and 7.5 individuals /leaf in control to 8.25, 7.0, 6.25, and 3.5, 3, and 2.5 individuals/leaf in the *C. carnea* and *M. pygmaeus*, respectively in all three planting cycles. Results also showed that in control and *M. pygmaeus*, the variation was only significant between cycles 1 and 3. While the *C. carnea* group showed a significant difference between cycles 1 and 3 and 1 and 2. Results also indicated that *M. pygmaeus* was more effective than *C. carnea* as a biocontrol agent against the larvae and mature *F. occidentalis*. Thus, using *M. pygmaeus* and *C. carnea* to manage the thrips damage is advised.

Keywords: soilless culture, vegetable, organic, natural enemies, insect pest management, hydroponic

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Introduction

Agriculture production, in the traditional sense, consumes many resources (FAO. 2017). Hydroponics is a type of agricultural system in which plants are grown without the use of soil. Beans, cucumbers, lettuce, tomatoes, and other crops have all been produced in hydroponics (Benis and Ferrão, 2018). One of the most challenging problems that hydroponic greenhouse growers face is insect and mite pests: whiteflies, spider mites, aphids, and thrips (Currey, 2017). *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) was

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initially observed in 1895 in California, USA, and since then has spread to several countries, becoming one of the critical vital agricultural insects of ornamental, vegetable, and fruit crops worldwide. Its overall intrusiveness is ascribed to global plant trade and pesticide opposition, which have resulted in the fast spread of this pest around the globe (Kirk and Terry, 2003; Reitz *et al*., 2020).

Since 1980, *F. occidentalis* has spread worldwide and is now found in at least 57 countries, making it the best-investigated part of Thysanoptera. (Morse and Hoddle,2006). An egg, double keenly eating larval phases (L1 and L2), quiescent prepupal (P1) and pupal (P2) phases, and a sexually dimorphous mature phase make up the lifecycle of *F. occidentalis*. According to He *et al*. (2019), thrips post-embryonic development is a hybrid of hemi- and holometabolism. Realizing the pest-crop injury association and identifying pest conditions are essential components of any integrated pest management decision-making process (Pedigo *et al*., 1986). As a result, economic thresholds for flower thrips types in pepper, tomato, and eggplant have been developed.

Funderburk (2011) noted that these economic limits help regulate the rapid-term demand for therapeutic thrips control in a specific crop to reduce dimpling, flecking, or secondary tospovirus spread. In many cropping systems, biological control has become a more viable option for reducing the overall thrips populations (Gao *et al*., 2012). The green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), is a generalist raider that preys on level insects, leafhoppers, psyllids, whiteflies, lepidopterans, thrips, and mites, among other soft-bodied arthropods (Cloyd, 2009; Principi and Cannard, 1984).

Chrysoperla carnea predation capacity against the lettuce aphid was lately investigated (Shrestha, 2011), but no data on the prey favorites of *C. carnea* versus *Nasonovia ribisnigri* and *F. occidentalis*, which both occur in lettuce growing areas at the same time, is available. Prey preference has a direct impact on the predator's ability to control its numerous prey (Xu and Enkegaard, 2009), and therefore, understanding the prey favorite is critical for determining the predator potential in situations where multiple pest types are common in the attention crop (Enkegaard *et al*., 2001).

Insecticide resistance, the resurgence of western flower thrips populations, and secondary pest destruction can all be avoided with a biologically based combined pest managing program (Weiss *et al.*, 2009). The efficient means to achieve thrips control in eggplant and pepper is to use the biological control elements of an incorporated pest managing program.

Reitz *et al.* (2003) noticed that the thrips adults are inhibited by a range of predaceous arthropods. Anthocorid species are the most effective thrips predators on the planet. The main real foes of thrips in pepper and eggplant, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) and *Orius pumilio* (Champion) (Hemiptera: Anthocoridae) are members of this family, with binary types found in Florida (Funderburk, 2009).

Herein, we separately applied *C. carnea* and *M. caliginous* at scheduled period distances on Batavia lettuce to verify whether the dual biocontrol substances would behave to enhance the effectiveness of biocontrol systems for regulating *F. occidentalis*. This report will provide a criterion for employing numerous biocontrol substances in pest control tactics.

Materials and Methods

Predators' cultures

Both predators' colonies were obtained from the biological control production unit - Aswan – Egypt. Both predators were reared and maintained on the egg of *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) as a food source at 25 ± 1 °C and 70 ± 5% RH and photoperiod of L16:D8 h. The rearing cages were kept at 26 ± 2 °C, 65 ± 5% RH, and photoperiod of L13:D11 h ± 1.

Experimental design

The study was performed in one greenhouse covered with a fine mesh net in El Mansouria, Giza - Egypt. A hydroponic system (Nutrient Film Technique) was installed to sustain the growth of the test plants in 2021 for three consecutive planting cycles.

This research had three treatments with five repeats each: T1 (control not including predators), T2 (larvae of *C.1q carnea*), and T3 (Nymph of *M. pygmaeus*).

The number of thrips per plant was estimated before the experiment. Both *C. carnea* and *M. pygmaeus* were released weekly with Spot Treatment: 10-20 larvae/m^2 and 0.25-5 per m2/release, respectively, although the preliminary amounts of *F. occidentalis* were approximately 50 individual/leaf.

Evaluation of percentage efficacy

Leaves of lettuce plants were checked once weekly to estimate the efficacy of the natural enemies. The adjusted effectiveness proportion was assessed using the Henderson and Tilton formula (Henderson and Tilton, 1955):

$$\%\text{Efficacy} = 1-\frac{\text{n in C before treating} \times \text{n in T after treating}}{\text{n in C after treating} \times \text{n in T before treating}}$$

Where:
n = No. of *F. occidentalis*.
T = Treated.
C = Control.

Statistical analysis

The statistical valuation of the data was done with one-way ANOVA *via* SPSS 18.0, tailed by Tukey's test, to assess the considerable variations among treatments at $P < 0.05$.

Results

While outcomes were extremely flexible, several things can be concluded. As presented in table (1) and figures (1 and 2), the amount of mature and immature Thrips per plant on foliage was impacted by *C. carnea* and *M.pygmaeus* on the Batavia lettuce. It was clear from these results that using *C. carnea* and *M. pygmaeus* caused greater declines in *F. occidentalis* larvae and mature (45.85 and 60.91%) than in control ones, respectively.

Through the experiment, the number of larvae and mature *F. occidental* was dropped. The *C. carnea* showed a slightly even pattern, with the highest peak on the 30th of August during planting cycle 1, while the lowest was recorded in the same cycle during the 6th of September. Moreover, *M. pygmaeus* showed the highest peak on the 2nd of September during planting cycle 1, while the lowest was recorded in the same cycle on the 16th of September.

It is clear from these results that using *C. carnea* and *M. pygmaeus*, (f =1.854, p = 0.087) caused greater decreases in *F. occidentalis* larvae and mature than in control ones in all planting cycles.

The effect of *M. pygmaeus* was higher than that of *C. carnea*. The population of *F. occidentalis* decreased from 8.75,7.75,7.5/leaf in control to 8.25, 7, 6.25, and 3.5, 3, 2.5 individuals/leaf in the *C. carnea* and *M. pygmaeus*, respectively in all three planting cycles.

Table 1 Mean numbers of *Frankliniella occidentalis* per leaf of lettuce after releasing adults of *Chrysoperla carnea* and *Macrolophus pygmaeus* at different periods.

Treatment	Number of *F. occidentalis* per leaf (Mean ± SE)						Total reduction (%)
	Population before treatments			Population after treatments			
	C1	C2	C3	C1	C2	C3	
C. carnea	60.0 ± 3.3	46.0 ± 3.3	42.0 ± 4.4	33.7 ± 2.9	28.1 ± 0.7	25.9 ± 0.5	45.85
M. pygmaeus	34.5 ± 1.4	38.0 ± 0.8	37.7 ± 1.3	14.8 ± 1.3	12.3 ± 0.3	10.5 ± 0.2	60.91
Control	38.3 ± 0.3	36.5 ± 1.2	37.7 ± 0.5	35.3 ± 0.9	31.9 ± 0.7	30.9 ± 0.9	

Sampling times from C1: August to October, C2: October to November, and C3: November to December.

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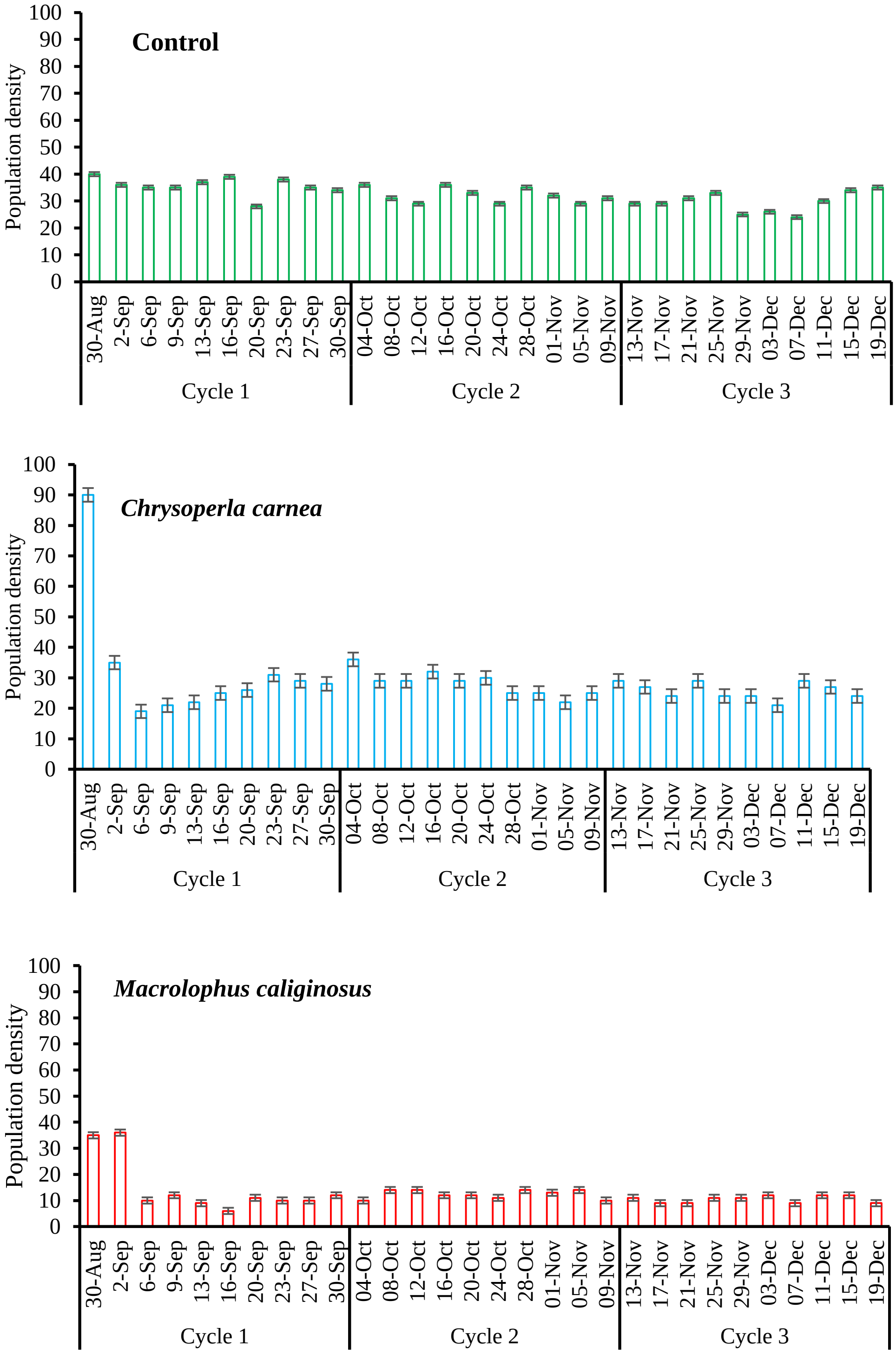

Figure 1 The number of thrips consumed by *Chrysoperla carnea* and *Macrolophus pygmaeus* infested Batavia lettuce under hydroponic cultivation.

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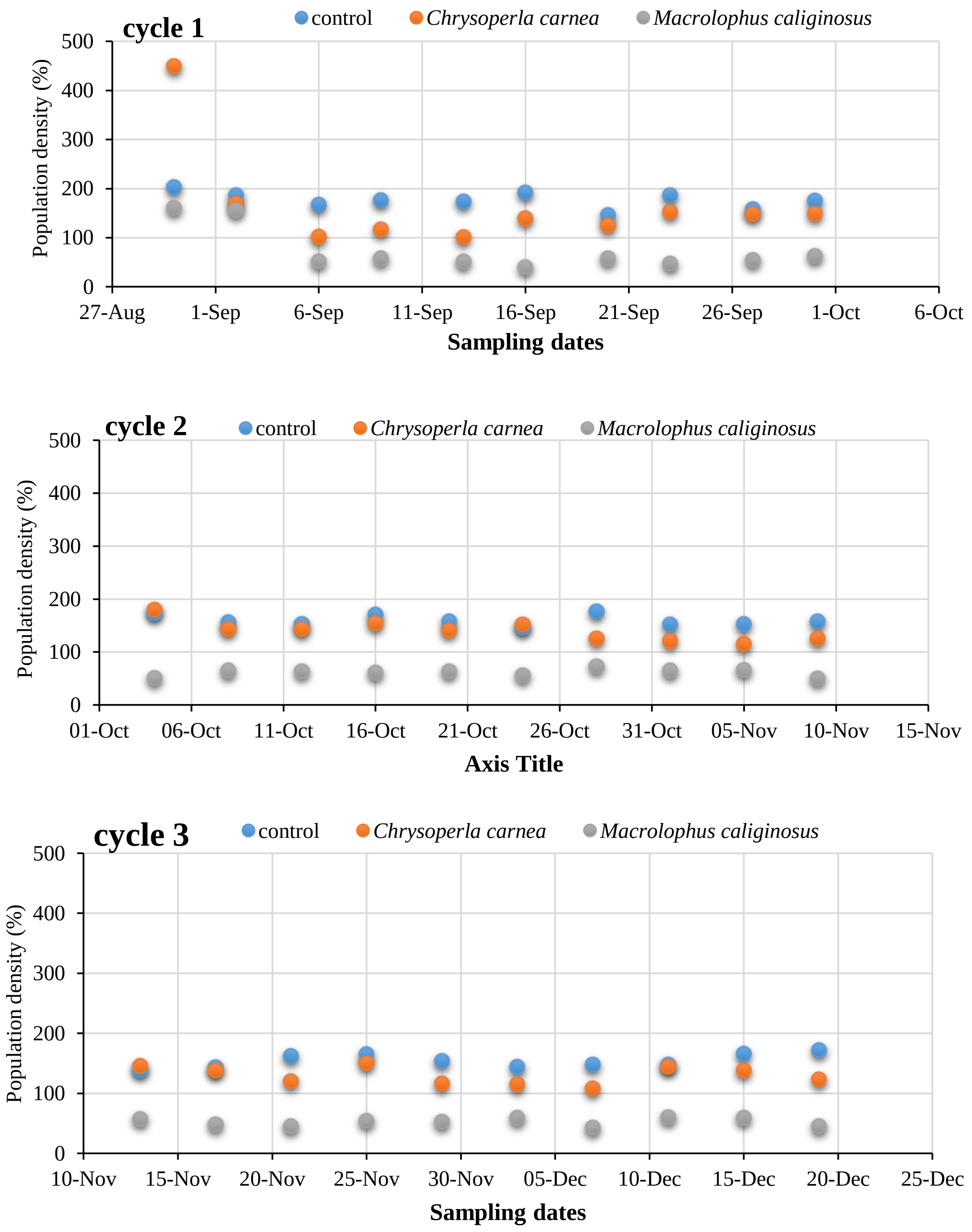

Figure 2 Mean percentage of *Frankliniella occidentalis* consumed by *Chrysoperla carnea* and *Macrolophus pygmaeus* in each planting cycle of Batavia lettuce under hydroponic cultivation.

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Overall, a significant variance ($P < 0.05$) between the control treatment and the others treatments *i.e*., control vs. *M. pygmaeus* (t = 21.668, $p < 0.001$),) and *C. carnea* (t = 3.934, $p < 0.001$) were observed.

Identically, there was a statistical interaction between predators and the cycle (f = 2.401, p = 0.049). Thrips population development was significantly reduced in the treatments when predators were released *C. carnea* vs. *Macrolophus* (f = 16.75, $p < 0.001$),

More detailed comparison cycles within different treated groups have been compared to reveal the variation in consumed insects during the experiment. Results showed that in control and *M. pygmaeus* only the variation was significant ($P < 0.05$) among cycles 1 and 3 (t = 2.545, p = 0.033). While *C. carnea* group shows a significant difference ($P < 0.05$) between cycle 1 and 3 (t = 4.163, $p < 0.001$) and cycle 1 and 2 (t = 2.944, p = 0.007).

For further inspection, a comparison among predators in the manner of each cycle has been compared in a way that could reveal the variation in consumed insects' numbers during the same cycle. Results indicate that all three treatments show clear significant variation ($P < 0.05$) between *C. carnea* vs. *M. pygmaeus*, cycle 1 (t = 10.707, $p < 0.001$), cycle 2 (t = 9.23, $p < 0.001$) and cycle 3 (t = 9.089, $p < 0.001$).

Discussion

These results emphasize that the reports on the function of biological control agents in hydroponic farming are scant. Based on the brief aforenoted review, the main findings indicate that *C. carnea* and *M. pygmaeus* played an important role in Reducing the western flower thrips that infest Batavia lettuce plants in hydroponic cultivation. Another promising result by Fantinou *et al*. 2009 was that *M. pygmaeus* was more effective than *C. carnea* as a biocontrol substance against *F. occidentalis*. Comparable findings were mentioned by numerous authors, where they used diverse plant, prey, or predator groupings and at lab circumstances. Wu *et al.* (2016) investigated the interactions between *Neoseiulus barkeri* (Mesostigmata: Phytoseiidae) and *Stratiolaelaps scimitus* (Mesostigmata: Laelapidae) to regulate *F. occidentalis* in eggplant and cucumber glasshouses. Results also successfully revealed that predators found populaces more easily on cucumbers than eggplants. Similarly, discharges of both *N. barkeri* and *S. scimitusalone* meaningfully decreased both larval and mature *F. occidentalis* masses, and joint discharges of *S. scimitus* and *N. barkeri* greatly amended the control of *F. occidentalis*.

The present results are consistent with Mo *et al*. (2013) and Chambers *et al*. (1993) reports, which dealt with *O. similis* in regulating *F. occidentalis* populations. Whereas the quantity of thrips consumed by *O. similis* amplified with the rising mass of *F. occidentalis* at each observed stage of the longitudinal heterogeneousness. The predation ratio quickly amplified at Lower thrips mass and slowly amplified at greater thrips mass. Whereas earlier scientists have noted that the rapacious tick *A. swirskii* has been described to efficiently regulate *F. occidentalis* on the cucumber and sweet peppers in glasshouses (Bolckmans *et al*., 2005; Calvo *et al*., 2006; Messelink *et al*., 2006).

Two other results from this study merit comment. Firstly, although predators were released weekly, it was noted that the number of thrips continuously increased during the first cycle, especially in the part where *C. carnea* was released. After observation, it was found that there is a whole line planted with red pepper (*Capsicum annuum*) near Batavia. It was the main source of thrips infestation, which caused the poor efficiency of *C. carnea*. Secondly, another reason for the reduced efficiency of predators was the continuous increase in the number of thrips, which had another source, the mango plantations next to the greenhouse, and the presence of some basil plants that made the infection consistently higher than the release of predators. Likewise, an extra elucidation, i.e. our understanding of the information, deserves a comment. For instance, scholars have recommended the existence of recently emerged *Chrysoperla externa* (Neuroptera: Chrysopidae)

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larvae evidenced to considerably decline in the *E. flavens* populaces on the peanut plants (*Arachis hypogaea* L.; Fabales: Fabaceae) under glasshouse circumstances, validating its possible use as a natural control substance (Rodrigues *et al*., 2014).

These results are consistent with the claim that the 3rd instar of *C. carnea* was the key insatiable when consuming the potato psyllid, *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae) (Ail-Catzim *et al*., 2012), while 3rd and 2nd instars of *C. externa* expended the major quantity of whiteflies on tomato leaves at laboratory circumstances (Castro *et al*., 2016).

The 3rd instar *C. carnea* larvae promptly preyed upon both aphids and thrips, displaying a fondness for aphids under lab. conditions (Shrestha and Enkegaard, 2013). The first instar larvae of each species expended fewer thrips at the blossom and vegetative phases than the other two instars.

Together, the present findings confirmed that this lessening in prey feeding could be due to two reasons: a) the minor size and lessened movement of the rapacious larvae, b) the thrips are inclined to hurdle or to have fleeting flies in the predator incidence, creating infestation by predator a hard duty. (Espino *et al.*, 2017).

No findings appear to have examined the predation of 3rd instar *C. carnea* on *F. occidentalis*. Nevertheless, Bennison *et al*. (1998) noted the predation of 36 *F. occidentalis* larvae per day by the 2nd instar of *C. carnea*.

Both *C. carnea* and *M. pygmaeus* are excellent biological control substances to realize an enhancive tactic for regulating *F. occidentalis* on vegetables. *F. occidentalis* can be controlled by consecutive releases of lacewing types, as was done for other predators. For instance, when the mites *Amblyseius cucumeris* Oudemans (Acari: Phytoseiidae), *Hypoaspis aculeifer* Canestrini (Acarina: Mesostigmata: Laelaptidae), and the bug *Orius insidious* (Hemiptera: Heteroptera: Anthocoridae) Say were concomitantly discharged, they attained a great regulation of *F. occidentalis* (Pergande) (Xu *et al*., 2011). A similar type of regulating *F. occidentalis* Population was done when the mites *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae) and the bug *Orius insidiosus* (Hemiptera: Anthocoridae) were discharged on Rosa hybrid (Chow *et al.*, 2010).

A similar conclusion was reached by Shrestha and Enkegaard (2013). In the 3rd instar *C. carnea* larvae freely preyed upon both aphids and thrips, with thrips transience changing between 40 and 90% and aphid transience between 52 and 98%. *Chrysoperla carnea* had a noteworthy favorite for *Nasonovia ribisnigri* (Homoptera: Aphididae) at two ratios (10 aphids: 80 thrips, 65 aphids: 25 thrips), but no favorite for either prey at the other levels.

There are some possible drawbacks regarding the current results. The first shortage concerns the growing period of Batavia lettuce. Meanwhile, the second potential limitation is using water sprinklers in the greenhouse to raise the humidity, which affects the efficiency of predators. It may sometimes cause them to be washed out and lost in large part.

Herein, we portrayed the useful functions of *C. carnea* and *M. pygmaeus* in governing western flower thrips that infest Batavia lettuce plants under a hydroponic system. The findings showed that *M. pygmaeus* was more effective than *C. carnea* as a biocontrol substance against larvae and adults of *F. occidentalis*. Therefore, using *M. pygmaeus* plus *C. carnea* to control thrips is greatly or strongly recommended.

Statement of Conflicting Interests

The authors state that there is no conflict of interest.

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ارزیابی‌تأثیر بالتوری سبز *Chrysoperla carnea* و *Macrolophus pygmaeus* به‌عنوان عوامل کنترل بیولوژیکی تریپس غربی گل*Frankliniella occidentalis* در کاهوی رقم باتاویا تحت کشت هیدروپونیک

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چکیده: مطالعات اندکی روی اثربخشی دشمنان طبیعی در کشت هیدروپونیک انجام شده است. هدف ما تعیین اثربخشی شکارگر بالتوری سبز *Chrysoperla carnea* و سن شکارگر *Macrolophus pygmaeus* برای کنترل تریپش غربی گل *Frankliniella occidentalis* در کشت هیدروپونیک کاهو رقم Batavia بود. بالتوری سبز و *M. pygmaeus* هر هفته به تعداد ۱۰-۲۰ حشره در مترمربع و ۰/۲۵-۵ حشره در مترمربع/رهاسازی شدند. به‌ترتیب بالتوری سبز و *M. pygmaeus* لارو و بالغین تریپس غربی گل (۴۵/۸۵ و ۶۰/۹۱ درصد) را نسبت به تیمارهای شاهد بسیار کاهش دادند. راندمان سن شکارگر بیشتر از بالتوری سبز بود. جمعیت تریپس غربی گل در سه دوره کاشت از ۸/۷۵، ۷/۷۵ و ۷/۵ حشره در برگ در شاهد به‌ترتیب به ۸/۲۵، ۷/۰، ۶/۲۵، و ۳/۵، ۳ و ۲/۵ حشره در برگ در بالتوری سبز و *M. pygmaeus* کاهش یافت. همچنین نتایج نشان داد که در گروه شاهد و *M. pygmaeus* این تنوع فقط بین دوره کاشت اول و سوم معنی‌دار بود. درحالی‌که گروه بالتوری سبز بین دوره‌های ۱ و ۳ و ۱ و ۲ تفاوت معنی‌داری نشان داد. نتایج نشان داد که کارایی سن شکارگر *M. pygmaeus* بسیار بیشتر از بالتوری سبز بود. به‌طور کلی استفاده از *M. pygmaeus* و بالتوری سبز برای مدیریت تریپس غربی گل توصیه می‌شود.

واژگان کلیدی: کشت بدون خاک، سبزی، ارگانیک، دشمنان طبیعی، مدیریت آفات، هیدروپونیک

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