Short title: Biocontrol of *F. occidentalis* and *B. tabaci* by mirids

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Comparative biocontrol potential of three predatory mirids when preying on sweet pepper key pests

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ABSTRACT

Pest management in protected sweet pepper crops mainly rely on biological control (BC) strategies. Recently, the zoophytophagous predatory mirids, *Nesidiocoris tenuis*, *Macrolophus pygmaeus*, and *Dicyphus maroccanus*, proved to be effective in the control of aphids on sweet pepper, for which the current biological control strategies have been meagre. The next step to integrate the possible use of these mirids in sweet pepper BC practices would be to ascertain their potential control on other sweet pepper pests. In this research, a comparative study to assess the establishment and the efficacy of *N. tenuis*, *M. pygmaeus*, and *D. maroccanus* on the two sweet pepper key pests; the thrips, *Frankliniella occidentalis*, and the whitefly, *Bemisia tabaci* was conducted. This study was carried out with two different temperature regimes, 20 °C and 27 °C, which simulated the mean temperatures registered in the two main crop cycles in Spain (the winter and summer planting period). Both, *N. tenuis* and *M. pygmaeus* were able to establish on sweet pepper and significantly reduced the number of *F. occidentalis* and *B. tabaci* adults, larvae and nymphs. *Macrolophus pygmaeus* had the highest density at 20 °C, whereas *N. tenuis* was more abundant at 27 °C. In contrast, *D. maroccanus* was less abundant under both temperatures studied; and did not reduce neither *F. occidentalis* nor *B. tabaci* infestations in this crop. None of the three mirids were observed to cause any damage to the pepper plant. The implications of these results applied to the use of mirids in sweet pepper crops are discussed.

Keywords: *Nesidiocoris tenuis*, *Macrolophus pygmaeus, Dicyphus maroccanus,* biological control, temperature regime.

1. Introduction

Protected sweet pepper (*Capsicum* spp.) is one of the most strategic horticulture crops, widely cultivated in South-eastern Spain. During the last twenty years, the ever demanding standards for healthy, residue-free products have pushed the growers to explore and adopt environmentally friendly strategies to manage sweet pepper pests (Calvo et al., 2009a; Van Lenteren 2012). The western flower thrips, *Frankliniella occidentalis* Pergande (Thysanoptera: Tripidae), is one of the most serious pests of sweet pepper, both in the greenhouse and in the open field (Tommasini and Maini, 1995; Van Driesche et al., 1998). In addition to direct damages, such as fruit abortion or fruit scarring caused by *F. occidentalis*, it may cause important indirect damages through its role as a vector for the tomato spotted wilt virus (TSWV) (Lacasa et al., 1991; Peters, 1996). Additionally, the sweet potato whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae), is considered to be a secondary pest which causes direct injury as a result of sap removal, honeydew build-up with sooty mould, physiological disorders, and the transmission of plant viruses (De Barro et al., 2011; Fortes et al., 2012). Therefore, the biological control of both pests in sweet pepper has become a priority in South-eastern Spain. Since the end of the last century many natural enemies of thrips and whiteflies have been reported and evaluated for their efficacy (Sánchez et al., 2000, Sánchez and Lacasa, 2002; Urbaneja et al., 2001, 2002; Stansly et al., 2005; Blom et al., 2003). All these studies have led to the current pest management strategy in sweet pepper, which is based on the release of the generalist biocontrol agents, the predatory mite *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) and the minute pirate bug *Orius laevigatus* Fieber (Hemiptera: Anthocoridae) (Calvo et al., 2009a). The augmentative release of both predators successfully manages two of the key pests of this crop, *B. tabaci* and *F. occidentalis* (Blom, 2008, Calvo et al., 2009a).

Despite the success of the current biological control based management program in sweet pepper, better control of aphids in this crop is still needed (Bloemhard and Ramakers, 2008; Belliure et al., 2008, Sanchez et al., 2011). Traditionally, aphids have been managed through the release of a combination of specialized predators, mainly the predatory midge *Aphidoletes aphydimiza* Rondani (Diptera: Cecidomyiidae) and parasitoids, mainly *Aphidius Colemani* Viereck (Hymenoptera: Braconidae) (Blom, 2008). However, the need for multiple releases of natural enemies increases the final cost of the biocontrol program (Messelink et al., 2011a). In addition, these releases can be disrupted by the abundance of hyperparasitoids (Sánchez et al., 2011), and by predator interference, where *A. swirskii* and *O. laevigatus* display intraguild predatory behaviour on the eggs of the midge (Messelink et al., 2011b; Hosseini et al., 2010). Therefore, there is a continuous need to identify and evaluate alternative natural enemies that can be used for the management of aphids in this crop.

Generalist predators are widely known to contribute to the management of a wide range of agricultural pest, including aphids, around the world (Perdikis and Lykouressis, 2004, Messelink et al., 2011a, 2015; Pérez-Hedo and Urbaneja, 2015; Sylla et al., 2016). Previous studies have demonstrated under laboratory conditions the zoophytophagous mirid predators, *Nesidiocoris tenuis* Reuter and *Macrolophus pygmaeus* Rambur (Hemiptera: Miridae), successfully feed upon the most commonly occurring sweet pepper aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae), also known as the green peach aphid (Perdikis and Lykouressis 2002, 2004; Valderrama et al., 2007; Fantinou et al., 2009). More recently, under semi-field conditions, Pérez-Hedo and Urbaneja (2015) observed how *N. tenuis*, *M. pygmaeus*, and *Dicyphus maroccanus* Wagner (Hemiptera: Miridae) significantly reduced the number of *M. persicae* in sweet pepper plants, reaching a level of aphid reduction close to 100%. Furthermore, Messelink et al. (2015) and De Backer et al. (2015) showed the release of *M. pygmaeus* and *D. tammaninii* Wagner (Hemiptera: Miridae) prior to infestation in combination with the application of supplemented food enhanced the management of *M. persicae* on sweet pepper. These results suggest the use of mirids in sweet peppers may just be the alternative needed in aphid management. However, the capacity of mirids to reduce thrips and whiteflies in sweet pepper crops has not been completely characterized.

To this end, we evaluated the efficacy of *N. tenuis*, *M. pygmaeus* and *D. maroccanus* as predators of thrips and whiteflies and also assessed the establishment of the mirids, on sweet pepper plants under two different temperature regimes (20 °C and 27 °C). Both selected temperatures simulated the registered means in the two main sweet pepper planting cycles in the Southeast of Spain.

2. Materials and methods

2.1. Insects and plants

Nesidiocoris tenuis, M. pygmaeus, and the whitefly, *B. tabaci* were obtained from a commercial supplier (NESIBUG® and MYRICAL®; Koppert Biological Systems, S.L., Águilas, Murcia, Spain). Each mirid species was provided in plastic bottles containing 500 individuals (mature nymphs and young adults), approximately 3-day-old specimens (FJ Calvo, Koppert BS; Personal Communication). Each predator species was released separately on sweet pepper plants “var. Lipari” (Dulce italiano, Mascarell semillas S.L, Valencia, Spain) inside 60 × 60 × 60-cm plastic cages (BugDorm-2 insect tents, MegaView Science Co., Ltd., Taichung, Taiwan) and supplied with *Ephestia kuehniella* Zeller eggs (Entofood®; Koppert B.S.) as additional food. *B. tabaci* adults were kept on sweet pepper plants (the same cultivar, as described above) inside plastic tents in 30 × 30 × 30-cm plastic cages (BugDorm-1 insect tents, MegaView Science Co., Ltd., Taichung, Taiwan), until their use. The individuals of the third mirid species, *D. maroccanus*, were obtained from a laboratory colony on pesticide free tomato seedlings “var. Optima” which had already been established in the Instituto Valenciano de Investigaciones Agrarias (IVIA), as described in Pérez-Hedo and Urbaneja (2015).

The *F. occidentalis* adults were also obtained from a colony previously established at IVIA in 2010; it was originally collected from Campo de Cartagena (Murcia, Spain). The thrips colony was raised on bean plants (*Phaseolus vulgaris* L., Fabales: Fabaceae). All stock colonies described above were housed in climatic chambers at 25 ± 2 °C, 65 ± 10% RH under a 14:10 h (L:D) photoperiod at IVIA.

The pesticide-free sweet pepper seedlings (*Capsicum annuum* L. var. "Lipari") were transplanted into plastic pots (8 × 8 × 8 cm) containing a mixture of natural soil with local peat moss and were housed in a climatic chamber under the same environmental conditions as described above. Plants (approximately 25 cm in height) with 12 fully developed leaves were used for the experiments described below.

2.2. Experimental design and sampling

The experiment was conducted in plastic screened cages (60 × 60 × 60-cm BugDorm-2, as described above), which were maintained in two identical cabinets of a glasshouse located at IVIA, under two different temperature regimes, 20 ± 2°C and 27 ± 2°C . The relative humidity was 65 ± 10% and the natural photoperiod was used. Temperature and relative humidity were maintained during the entire duration of the experiment by the climate controller Ambitrol 500 (Sistemes Electrònics Progrès SA, Bellpuig. Spain). The experiment was carried out during the eleven weeks between mid-March to the beginning of June, 2015.

To evaluate the efficiency of *N. tenuis*, *M. pygmaeus*, and *D. maroccanus* to control a mixed infestation of *F. occidentalis* and *B. tabaci* on sweet pepper a randomized complete block design with four treatments (release of *N. tenuis*, release of *M. pygmaeus*, release of *D. maroccanus* and a control without predator release) replicated four times each (cage=replicate) were used in both of the two glasshouse cabinets. Mirids were released simulating the strategy of predator in first (pre-plant release) (Calvo et al., 2012). This strategy entails mirids being released in the nursery 5-7 days before transplanting the sweet pepper plants upon which mirid individuals had already laid eggs; therefore, small nymphs and adults were still present. In each replicate, eight healthy sweet pepper plants (25 cm high) and four couples (male/female) of each species of mirid were introduced on the same day (1 adult/plant). Each mirid species was separately released in quadruplets. The control treatment did not receive mirid releases. During the first two weeks of the experiment, approximately 0.1 g / plant of frozen eggs of *E. kuehniella* were equally distributed on the plants by manually sprinkling. The addition of this alternative food facilitated mirid establishment and oviposition (Urbaneja-Bernat et al., 2015). The plants were irrigated twice a week throughout the experiment.

Two weeks after the release of mirids, 8 couples (male/female) (5 adults/m^2) of *F. occidentalis* and 16 couples (10 adults/m^2) of *B. tabaci* were introduced per cage eight times (1 infestation per week). Both pests were separately introduced into Petri dishes that were then left open at the base of the plant in each of the cages. These selected rates were chosen to simulate a strong and early whitefly and thrips infestation.

One week after the first pest infestation, the samplings were started in both of the glasshouse cabinets at 20 °C and 27 °C. From four randomly selected plants per replicate three leaves (one from the upper, one from middle, and one from the lower part of the plant) were inspected and the number of live *F. occidentalis* and *B. tabaci* adults, larvae, and nymphs were recorded. The total number of mirid adults and nymphs was recorded from the entire surface of same plants. Eight evaluations (one per week) were conducted. Special care was always taken to sample the control cages first and then the cages containing the predators, to reduce the risk of accidental contamination among the treatments.

2.3. Statistical analysis

The total number of *F. occidentalis* and *B. tabaci* per sampled leaf and the total number of mirids per plant were log (x+1) transformed prior to analysis using Generalized Linear Mixed Models (GLMM). Treatment was considered to be a fixed factor, while time in weeks, a random one. Each GLMM used a normal distribution and identity link function. Untransformed values are presented in the figures. Whenever a significant difference was found, pairwise comparisons of the fixed factor levels were performed with the least significant difference (LSD) post-hoc test ($P<0.05$). To calculate the percentage of *F. occidentalis* and *B. tabaci* reductions Abbott's formula was applied (Abbott, 1925) using the number of *F. occidentalis* and *B. tabaci* accumulated at the end of the experiment (week 8; the area under the duration of the experiment incidence curve) (Calvo et al., 2009b). To know whether differences between the percentages of reduction existed, data were log transformed then a one-way analysis of variance (ANOVA) followed by comparison of means (Tukey's test) at $\alpha < 0.05$ or one-tailed Student's *t* test ($P < 0.05$) was performed. The results were expressed as the means ± standard error.

3. Results

3.1. Frankliniella occidentalis management

In the glasshouse at 20 °C, the three species of mirids significantly reduced the populations of *F. occidentalis*, when compared to the control (Fig. 1a) (Table 1). However, the number of *F. occidentalis* was significantly lower in the cages where *N. tenuis* and *M. pygmaeus* were released when compared to the cages in which *D. maroccanus* was released. No significant difference in the percentage of *F. occidentalis* reduction was found between the sweet pepper plants that received releases of *N. tenuis* or *M. pygmaeus*. At week 8, *N. tenuis* and *M. pygmaeus* reduced the infestation of *F. occidentalis* by 82% and 87%, respectively. In contrast, *D. maroccanus* only achieved a 33% reduction, which was significantly lower when compared to the reduction achieved by *M. pygmaeus* and *N. tenuis* ($F_{2\text{-}11} = 12.42$; $P = 0.003$) (Fig. 1b). Similar results were recorded from cages maintained in the glasshouse at 27 °C (Table 1). *N. tenuis* and *M. pygmaeus* were more voracious and reduced the infestation of *F. occidentalis* by 89% and 90%, respectively, at week 8 ($F_{2\text{-}11} = 16.95$; $P = 0.0009$). *Dicyphus maroccanus* was less efficient and reduced 45% of the *F. occidentalis* population when compared to control treatment (Fig. 1d). At this temperature, no differences were observed between the percentages of reduction of *F. occidentalis* in sweet pepper, which received releases of *N. tenuis*, and those which received *M. pygmaeus* (Table 1).

3.2. *Bemisia tabaci* management

The number of *B. tabaci* per sampled leaf in the cages maintained in the glasshouse at 20 °C was low for all the treatments. The release of *M. pygmaeus* and *N. tenuis* significantly reduced the *B. tabaci* infestation when compared to the *D. maroccanus* and control cages (Fig. 2a) (Table 1). No significant differences were found between the numbers of *B. tabaci* counted in *D. maroccanus* and control cages. The infestation by *B. tabaci* at week 8 was reduced by 82% and 65% by *M. pygmaeus* and *N. tenuis,* respectively (t_6 = 2.263; P= 0.108) (Fig. 2b). A similar trend was observed when the experiment was conducted at 27 °C; however, under this temperature the three mirid species significantly reduced the *B. tabaci* infestation when compared to the control. The number of *B. tabaci* was significantly lower in the *N. tenuis* and *M. pygmaeus* cages when compared to that in the *D. maroccanus* cages (Fig. 2c) (Table 1). A reduction of 96% of the infestation was obtained by *M. pygmaeus* and *N. tenuis*, whereas, *D. maroccanus* was less efficient and only reduced the *B. tabaci* populations by 46% ($F_{2\text{-}11}$ = 7.06; P = 0.015) (Fig. 2d).

3.3. *Mirid populations*

At 20 °C, *M. pygmaeus*, with an average of 1.6 ± 0.2 individuals/plant, was significantly more abundant than *N. tenuis* (1.15 ± 0.3), which in turn was higher than *D. maroccanus* (0.3 ± 0.2) (Fig. 3a) (Table 2). In contrast, when the experiment was conducted at 27 °C, *N. tenuis* was the most abundant predator with an average of 2.1 ± 0.4 individuals/plant, which was significantly higher than both the *M. pygmaeus* and *D. maroccanus* populations (Table 2). Significant differences were obtained between the *M. pygmaeus* (1.2 ± 0.2) and *D. maroccanus* (0.25 ± 0.05) population numbers, with the latter being very low throughout the entire experiment (Fig. 3b) (Table 2).

4. Discussion

Our results show that the pre-plant release strategy of the three selected predatory mirids, supported by the addition of *E. kuehniella* eggs, successfully established on sweet pepper plants although the number of mirids per plant was much lower in the case of *D. maroccanus*. Accordingly, the number of individuals established by the release and augmentation of *N. tenuis* or *M. pygmaeus* before the infestation of thrips and whiteflies resulted in continuous suppression of both pests. The low abundance of *D. maroccanus* was relative to the level of control reached by both pests, which remained around 40% in both temperature regimes.

Although, the members of Miridae are common predators in Mediterranean agroecosystems and spontaneously colonize various agricultural crops, including sweet pepper (Perdikis and Lykouressis, 1996; Tavella et al., 1997; Castañé et al., 2004; Gabarra et al., 2004), their commercial use in this crop is underrepresented. The mirid predators are known to be generally associated to hairy plants (Wheeler, 2001), but our results and previous studies have shown their establishment and reproduction to also be possible in plants lacking hair and or trichomes (Perdikis and Lykouressis, 2004; Urbaneja et al., 2005; Barbara et al. 2011; Messelink et al., 2015; Pérez-Hedo and Urbaneja, 2015).

Our results illustrated differences in the abundance of each predator species in the two temperatures tested. *Macrolophus pygmaeus* showed strong preference for the lower temperature tested where it was significantly more abundant in all the released cages when compared to *N. tenuis* and *D. maroccanus*. Conversely, *N. tenuis* was the most abundant at 27 °C. These trends linked to temperature are in accordance with the observations made by Sánchez et al. (2003), who reported that *M. pygmaeus* was more abundant than *N. tenuis* in the spring and early summer in horticultural crops in inland areas of South-eastern Spain, whereas *N. tenuis* was the predominant species found naturally in the coastal areas where temperatures were higher. Previous studies confirmed that *N. tenuis* is more thermophilous than any of the other Dicyphinae members, such as *M. caliginosus* Wagner, *M. pygmaeus*, and *D. tamaninii* Wagner (Sánchez et al., 2009). The optimum temperature required by *N. tenuis* ranges between 20 and 30°C, with a high fertility rate observed at 30°C, that allows this mirid better adaptation to high temperatures (Sánchez et al., 2009; Hughes et al., 2009, 2010). Indeed, in this research we observed how *N. tenuis* was able to double its population at 27 °C.

Temperature is not the only factor that could have influenced the distinct development of the mirids. The availability of prey could also have influenced the population dynamics obtained. Prey scarcity was more evident at 20 °C, especially in the case of *B. tabaci*, which is better adapted to higher temperatures (Bonato et al., 2007; Naranjo et al., 2010). *M. pygmaeus* can continue its immature development by feeding exclusively on the plant tissue although its survival is highly affected (Perdikis and Lykouressis, 1996, 2000; Portillo et al., 2012). However, *N. tenuis* is prey dependent (Urbaneja et al., 2005), which could have accentuated the thermal differences between both species even more. Prey preference and switching behaviour to feeding on the most preferred prey are additional characters to be considered when evaluating the potential of polyphagous predators in multi-pest agroecosystems. However, in the case of Hemipteran predators, developmental rate and fecundity are usually enhanced when they are fed multi-prey diets (Wheeler, 2001), which may indicate that even in the case of strong preferences for one prey, the necessity to diversify the diet can be very influential. Mixed diets are known to have a positive effect on reproduction in some predator species (Evans et al., 1999). For example, in greenhouse cucumber, better control was achieved by the predatory mite *A. swirskii* due to the positive effect of a mixed diet of thrips and whiteflies (Messelink et al., 2008).

Macrolophus pygmaeus being slightly less abundant at 27 °C than at 20 °C was more effective at 27 °C than at 20 °C. The strong reduction in *B. tabaci* populations in the presence of *F. occidentalis* and *vice versa* could be due to an increased response by *M. pygmaeus* to higher prey availability (Holt, 1977; Holt and Lawton, 1994). Several previous studies support the idea of numerical responses by *M. pygmaeus* depending on the number of available prey (Fauvel et al., 1987; Alómar et al., 2002). In accordance with our results, Fantinou et al. (2008), observed an increase in the predation rate of *M. pygmaeus* on *M. persicae* at 30 °C where the amount of susceptible prey was higher than at lower temperatures where the availability of prey was lower. The reasons for this shift in the predator's behaviour when foraging at higher temperatures may be related to increased metabolic rates and behavioural changes of the predator and/or prey, which could result in more successful predatory searches (lower search time) or less effective defence by the prey (Fantinou et al., 2008).

The third tested mirid species, *D. maroccanus*, failed to successfully establish throughout the length of the experiment at both temperatures studied. In previous studies, *D. maroccanus* was observed to successfully establish itself and prey on *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) on tomato crops (Abbas et al., 2014), and on *M. persicae* on sweet pepper plants (Pérez-Hedo and Urbaneja, 2015). The reasons that could explain its failure to establish itself remain unclear, but perhaps thrips and whiteflies were not suitable prey species for this predator. As a result of the low abundance of *D. maroccanus,* neither of the two pests were adequately suppressed, despite the lower population levels of them when compared to the control cages. All the plants treated with *D. maroccanus* appeared unhealthy at the end of the experiment, with no visual differences observed between them and the control cages.

Our results are not the first to describe the efficiency of *N. tenuis* and *M. pygmaeus* in managing thrips and whiteflies; this has already been seen in several agricultural crops (Castañé et al., 1996; Riudavets and Castañé, 1998; Blaeser et al., 2004; Bonato et al., 2006; Sánchez and Lacasa, 2008; Calvo et al., 2012; Malo et al., 2012). However, in the case of sweet pepper, this is the first study that evaluates the effectiveness of both mirids when pre-plant release was done without combining them with other natural enemies. Indeed, Calvo et al. (2009a) evaluated the potential predation of *N. tenuis* combined with that of the parasitoid, *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae), and *A. swirskii*. In that study, the combined release of *N. tenuis* with *A. swirskii* did not improve the biological control of *B. tabaci* on sweet pepper. However, Messelink and Janssen (2014) confirmed the combination of *M. pygmaeus* and *O. laevigatus* to enhance the biological control of *F. occidentalis* and *M. persicae* in sweet pepper crops.

Overall, our results, together with those of previous studies (regarding the efficiency of mirids in managing aphids on sweet pepper, could help to develop new strategies for pest management in commercial sweet pepper crops using generalist predators. Moreover, the efficacy of *N. tenuis* and *M. pygmaeus* preying upon a mixed diet of sweet pepper pests including aphids warrants further research. Biological control agents are frequently used in combination; however, the success of a biological control program can be disrupted by direct and or indirect interactions, such as competition, apparent competition, intraguild predation, and behavioural interference, between natural enemies. Hence, we have planned a study on the compatibility of *N. tenuis* and *M. pygmaeus* with other natural enemies already adapted to sweet pepper, such as *A. swirskii*, to evaluate their combined efficacy in this crop.

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Tables

Table 1

P values for the pairwise comparison of the number of *F. occidentalis* and *B. tabaci* per leaf which received a release of *D. maroccanus* (*Dm*), *M. pygmaeus* (*Mp*), *N. tenuis* (*Nt*) and control without release (C). Values in bold correspond to significant differences between the treatments.

Treatments	**20 °C**				**27 °C**			
	F. occidentalis		*B. tabaci*		*F. occidentalis*		*B. tabaci*	
	t_{124}	***P***	t_{124}	***P***	t_{124}	***P***	t_{124}	***P***
C vs. *Dm*	**2.881**	**0.005**	1.736	0.085	**3.914**	**< 0.001**	**2.509**	**0.013**
C vs. *Mp*	**6.572**	**< 0.001**	**5.413**	**< 0.001**	**6.677**	**< 0.001**	**5.257**	**< 0.001**
C vs. *Nt*	**5.950**	**< 0.001**	**4.456**	**< 0.001**	**6.601**	**< 0.001**	**5.262**	**< 0.001**
Dm* vs. *Mp	**3.691**	**< 0.001**	**3.677**	**< 0.001**	**2.763**	**0.007**	**2.748**	**0.007**
Dm* vs. *Nt	**3.070**	**0.003**	**2.720**	**0.007**	**2.687**	**0.008**	**2.753**	**0.007**
Mp* vs. *Nt	0.621	0.536	0.957	0.340	0.076	0.940	0.005	0.996

Table 2

P values for the pairwise comparison of the number of mirids (adults + nymphs) per plant which received *D. maroccanus* (*Dm*), *M. pygmaeus* (*Mp*), and *N. tenuis* (*Nt*) releases. Values in bold correspond to significant differences between the treatments.

Treatments	**20 °C**		**27 °C**	
	t_{93}	P	t_{93}	P
Dm* vs. *Mp	**7.292**	**< 0.001**	**3.992**	**< 0.001**
Dm* vs. *Nt	**4.886**	**< 0.001**	**7.754**	**< 0.001**
Mp* vs. *Nt	**2.406**	**0.018**	**3.762**	**< 0.001**

Figure legends

Fig. 1. (a) Number (mean ± SE) of *F. occidentalis* (adults + larvae) per sweet pepper leaf at 20 °C, (b) percentage reduction (Abbott) (mean ± SE) of *F. occidentalis* individuals at 20 °C (c) number (mean ± SE) of *F. occidentalis* (adults + larvae) per sweet pepper leaf at 27 °C, and (d) percentage reduction (Abbott) (mean ± SE) of *F. occidentalis* individuals at 27 °C in a glasshouse experiment comparing the effectiveness of the mirid predators, *N. tenuis*, *M. pygmaeus*, and *D. marocannus* at different time intervals under the two temperature regimes mentioned above. Bars with different letters are significantly different (ANOVA, Tukey's multiple comparison test $\alpha < 0.05$).

Fig. 2. (a) Number (mean ± SE) of *B. tabaci* (adults + nymphs) per sweet pepper leaf at 20 °C, (b) percentage reduction (Abbott) (mean ± SE) of *B. tabaci* individuals at 20 °C (c) Number (mean ± SE) of *B. tabaci* (adults + nymphs) per sweet pepper leaf at 27 °C, and (d) percentage reduction (Abbott) (mean ± SE) of *B. tabaci* individuals at 27 °C in a glasshouse experiment comparing the effectiveness of the mirid predators, *N. tenuis*, *M. pygmaeus*, and *D. marocannus* at different time intervals under the two temperature regimes mentioned above. Bars with different letters are significantly different (ANOVA, Tukey's multiple comparison test ($\alpha < 0.05$).

Fig. 3. (a) Number (mean ± SE) of *N. tenuis*, *M. pygmaeus*, and *D. marocannus* (adults + nymphs) per sweet pepper plant at different time intervals under two temperature regimes, (a) 20 °C and (b) 27 °C.

Fig. 1.

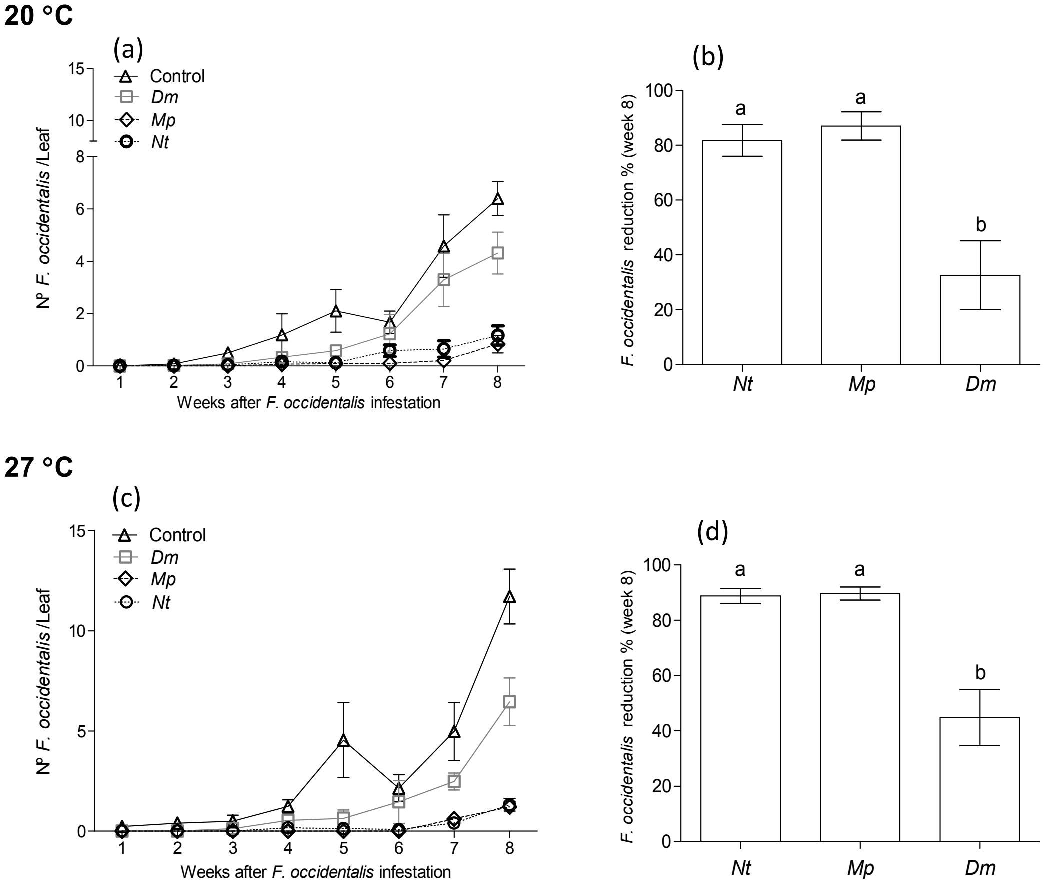

20 °C
(a)
Control
Dm
Mp
Nt
Nº F. occidentalis /Leaf
Weeks after F. occidentalis infestation
(b)
F. occidentalis reduction % (week 8)
a
a
b
Nt
Mp
Dm
27 °C
(c)
Control
Dm
Mp
Nt
Nº F. occidentalis /Leaf
Weeks after F. occidentalis infestation
(d)
F. occidentalis reduction % (week 8)
a
a
b
Nt
Mp
Dm

Fig. 2.

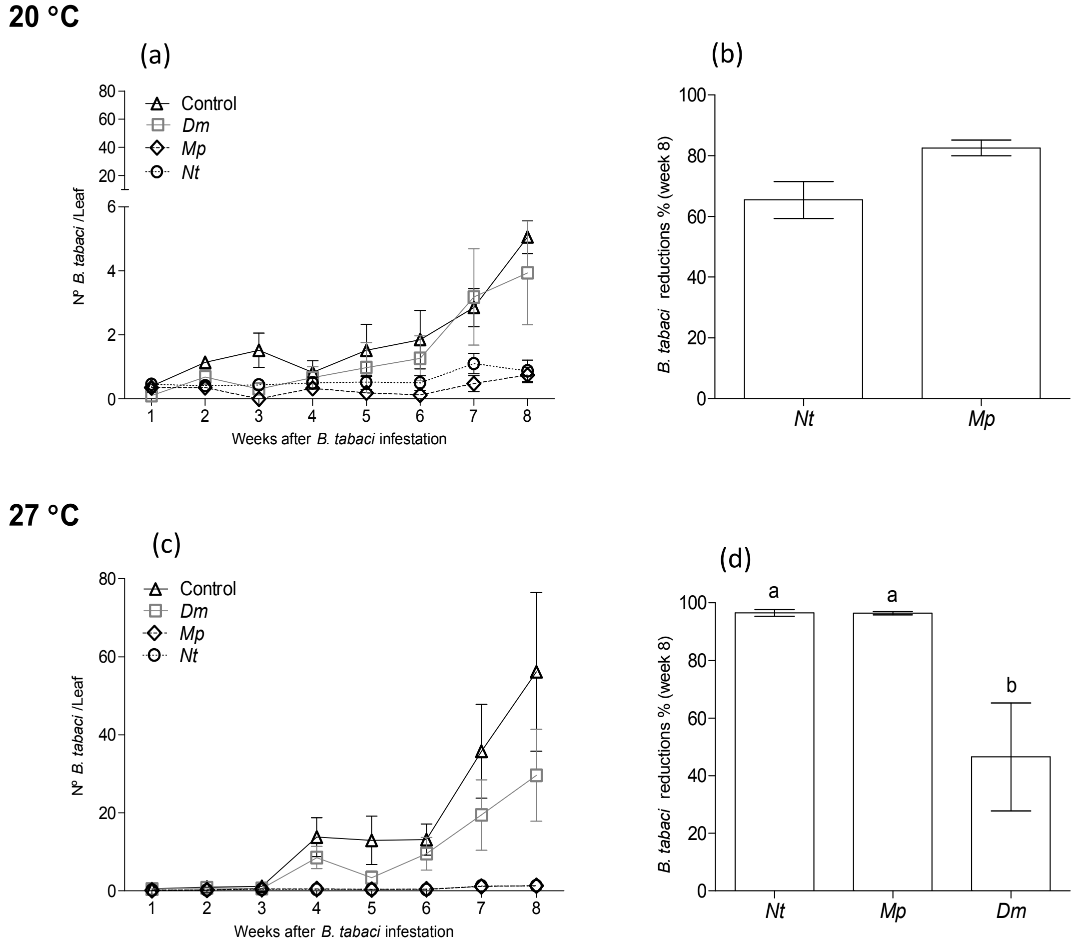
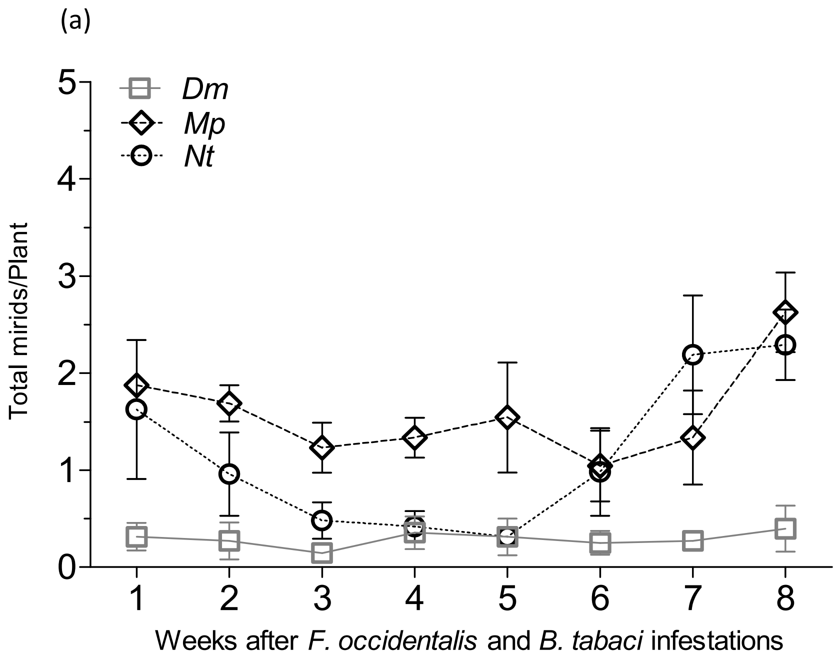
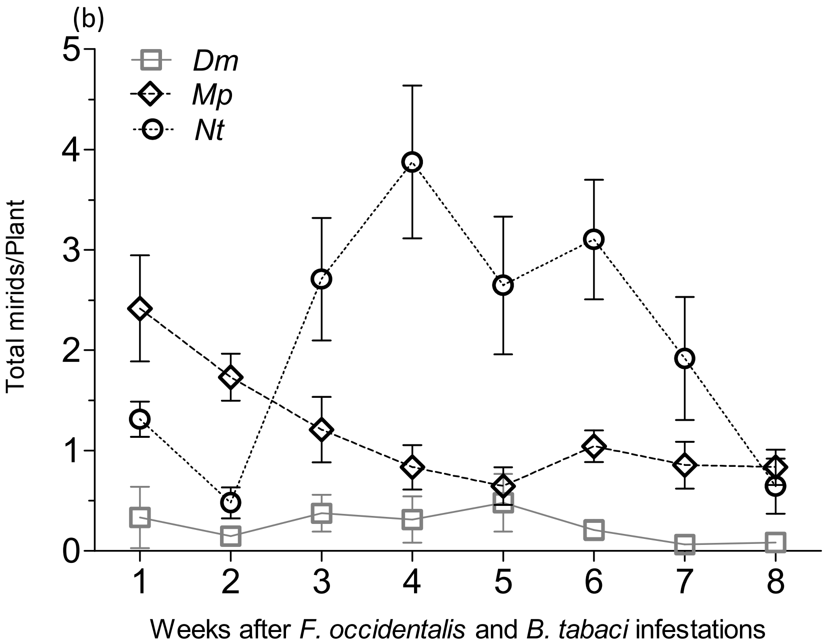

20 °C
(a)
Control
Dm
Mp
Nt
Nº B. tabaci /Leaf
Weeks after B. tabaci infestation
(b)
B. tabaci reductions % (week 8)
Nt
Mp
27 °C
(c)
Control
Dm
Mp
Nt
Nº B. tabaci /Leaf
Weeks after B. tabaci infestation
(d)
a
a
b
B. tabaci reductions % (week 8)
Nt
Mp
Dm

Fig. 3.

20 °C


(a)
Dm
Mp
Nt
Total mirids/Plant
0
1
2
3
4
5
1 2 3 4 5 6 7 8
Weeks after *F. occidentalis* and *B. tabaci* infestations

27 °C


(b)
Dm
Mp
Nt
Total mirids/Plant
0
1
2
3
4
5
1 2 3 4 5 6 7 8
Weeks after *F. occidentalis* and *B. tabaci* infestations