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Research Article

Control of *Trialeurodes vaporariorum* (Westwood) adults on glasshouse-grown cucumbers in four different growth substrates: an efficacy comparison of foliar application of *Steinernema feltiae* (Filipjev) and spraying with thiamethoxamn

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Abstract: In a glasshouse experiment, the effectiveness of the entomopathogenic nematode (EPN) *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) was compared with thiamethoxam for the control of adults of the greenhouse whitefly (GWF), *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae), on slicer cucumbers. In a period from mid June to the end of August (2007 and 2008), cucumbers were grown in 4 different growth substrates: expanded perlite, expanded vermiculite, light expanded clay, and peat. A suspension of the nematode (2500 infective juveniles mL^{-1}) was applied to cucumbers 5 times in 2007 and twice in 2008, whilst an insecticide thiametoxam at the recommended dose (0.7 g L^{-1}) was used 3 times in 2007 and twice in 2008. Adults of GWF showed sensitivity to the attack of *S. feltiae*, and also showed sensitivity to the application of the thiamethoxam. Different control strategies had greater influence on the mean mass of cucumbers than the type of growth substrate. In the control treatment, where we found the highest number of GWF adults in both years, the mean mass of cucumbers was the lowest. In 2007, the mean number of GWF adults per leaf was significantly the lowest in treatment with thiametoxam, while in 2008 there were no differences between the influence of thiamethoxam and EPNs. Light expanded clay aggregate appeared to be a less appropriate growth substrate, as cucumbers grown on this type of substrate produced the lowest number of fruits per plant.

Key words: Biological control, cucumbers, entomopathogenic nematodes, greenhouse, insecticide, greenhouse whitefly

Introduction

The greenhouse whitefly (GWF), *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae), is an important polyphagous pest of various crops (Vet et al. 1980; Johnson et al. 1992). Adults and larvae cause damage to plants by sucking the phloem sap, encouraging the growth of sooty molds on leaves, and transmitting some plant viruses (Coffin and Coutts 1995; Guzman et al. 1997). In northern climates, this whitefly usually lives in glasshouses on wild plants, or in summer on adjacent plants outside. Further south, adults may also overwinter on wild plants growing outdoors if the climatic conditions are not too severe. The development period from egg to adult requires about 25-30 days at 21 °C, and 22-25 days at 24 °C. GWF

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can live for months, and oviposition time can exceed the development time of immatures, resulting in overlaping generations. Optimal relative humidity is about 75%-80%, and the developmental threshold for all stages is about 8.5 °C (Capinera 2001). It is well known that the greenhouse whitefly has a strong preference for cucumbers grown in greenhouses (Jeon et al. 2009).

The extensive use of pesticides against potential pests has resulted in the appearance of pesticide resistance in many glasshouse pests (Yorulmaz and Ay 2009), including *T. vaporariorum* (Gorman et al. 2001), and phytotoxicity and pesticide residue problems on vegetables (Quinlan 1988). The demand for a reduction in pesticide use and the requirement for residue-free food have resulted in an increasing interest in biological control systems for use in glasshouses. Thiamethoxam is a chloronicotinyl insecticide and is widely used to control homopteran pests (Elbert et al. 1998), and has been shown to have high efficacy against GWF (Bi et al. 2002).

Entomopathogenic nematodes (EPNs) carry species-specific symbiotic bacteria which, after nematodes infect their insect hosts, are released into the hemolymph of the host. Only infective juveniles (IJs) are able to infect the insect host (Kaya 1990). Several attempts have been made to use EPNs as biocontrol agents against target pests located on the crop foliage but early results were not encouraging in glasshouses (Hara et al. 1993) or fields (Kaya et al. 1981; Hara et al. 1993; Grewal and Georgis 1998; Susurluk and Ehlers 2008). However, recent development of more effective application techniques/tools for nematodes promises to improve the efficacy of nematodes against foliar pests (Laznik et al. 2010), particularly under glasshouse conditions (Trdan et al. 2007).

The use of growth substrates is an increasingly important method for cucumber production in glasshouses (Parks et al. 2004). The advantage of this type of production in comparison with conventional (soil) production is that, beside a controlled nutrient supply, there is also a replacement of inappropriate substrate, particularly in cases where pest organisms occur naturally in the substrate (Schnitzler 2005). The usage of EPNs in these kinds of production systems can be through foliar application, which provides rapid activity of these biological agents (Trdan et al. 2007).

Previous research on foliar application of *Steinernema feltiae* (Filipjev) (Rhabditida: Steinernematidae) suspension showed its high efficacy in controlling Colorado potato beetle (*Leptinotarsa decemlineata* [Say]) (Laznik et al. 2010), larvae of sweetpotato whitefly (*Bemisia tabaci* [Gennadius]) (Cuthberston et al. 2003), and western flower thrips (*Frankliniella occidentalis* [Pergande]) (Trdan et al. 2007).

We aimed to study the efficacy of numerous applications of this species against adults of GWF on glasshouse-grown cucumbers, and to compare the results with the efficacy of the insecticide thiamethoxam. We also aimed to see if the number of GWF adults is negatively correlated with the yield of the cucumbers, as was documented in one related article (Johnson et al. 1992), where the researchers discovered this correlation with GWF immature stages and tomato yield.

Materials and methods

Study site and material

In 2007 and 2008, a greenhouse experiment was conducted at the experimental field of the Biotechnical Faculty in Ljubljana (46°04′N latitude, 14°31′E longitude, 299 m above the sea level), Slovenia. The study was conducted in a greenhouse where massive occurrence of greenhouse whitefly on different hosts (cucumber, eggplant, tomato, bean) had been recorded in the previous years.

Seeds of the slicer cucumber, cv. Jazzer F1, were sown in 92 seedling trays filled with fertilized peat. After seedling emergence, the transplants were overhead irrigated as needed. When they reached 3 fully expanded leaves, the seedlings were fertigated weekly with 50 mg L^{-1} of soluble fertilizer ($15N\text{-}15P_2O_5\text{-}15K_2O$). After the nursery period, the transplants were transferred to the high-roof passive-ventilated greenhouse (width 18 m, length 24 m, east-west orientation) on 10 June. Plants were set into 10 m long by 0.4 m wide by 0.3 m tall black plastic sleeves (plots), and then placed 0.8 m apart in rows to give a population of 4 plants m^{-2}. To allow drainage, 10 holes about 1.5 cm in diameter were drilled about 5 cm from the bottom of the containers.

The sleeves were filled with 1 of 4 different growth substrates: expanded perlite (bulk density: 160 kg m^{-3}), expanded vermiculite (medium granulation, pH 7.4), light expanded clay aggregate (grain size 8-16 mm), and peat (Humin substrate N2 Neuhaus). All plants were fertigated with the same (drip irrigation) system and same rate of nutrients, which consisted of 8-18-26 soluble fertilizer, calcium nitrate, and magnesium sulfate. The amount of added water next to fertigation (there was no irrigation) was dependent on moisture of substrate, which was measured by tensiometer. The city water source showed a pH of 6.8 and so was adjusted to 7.2 with nitric acid. A trellis system and high tensile fencing wire was used to support the cucumbers to a height of 3 m.

Greenhouse experiment

In 2007 and 2008 the glasshouse temperature at the time of the experiment was 26.0-45.5 °C (0800-2000) and 14.0-25.0 °C (2100-0700), while the relative humidity was 17.5%-68.0% (0800-2000) and 55.0%-90.0% (2100-0700). Four plants in each sleeve (sub-plot) were sprayed with a suspension of *S. feltiae* (the biopreparation Entonem, manufacturer: Koppert B.V., Berkel en Rodenrijs, the Netherlands; supplier: Zeleni hit d.o.o., Ljubljana, Slovenia). A standard rate of 2500 infective juveniles (IJs) *S. feltiae* per mL of water was used. Four plants were sprayed with thiamethoxam (0.7 g L^{-1}; 0.07% Actara 25 WG; manufacturer: Syngenta; supplier: Syngenta Agro d.o.o., Ljubljana, Slovenia), and the 4 control plants were sprayed with water. Before spraying each suspension of nematodes, 0.05% of the surfactant Nu-Film-17 (a.i. di-1-p-methene, 96%; manufacturer: Lances Links SA, Geneva, Switzerland; supplier: Karsia Dutovlje d.o.o., Ljubljana, Slovenia) was added to the sprayer to enable the suspension to move more effectively across the leaf surface and enhance GWF location.

In 2007, the first application of the biological agents (before application the viability of the nematodes was checked) and insecticide (12 June) occurred when the first GWF adults were observed on the leaves of cucumbers. Weekly applications thereafter (1, 2, 3, 4, and 5 weeks after the first application [AFA]) of *S. feltiae* suspension (at glasshouse temperature) were made by an injector hollow cone nozzle TVI 80 02 attached to motor-operated backpack sprayer. Sprays with thiamethoxam (12 June, 3 and 5 AFA) were applied at the same time of the day (early evening) using a backpack sprayer with an injector nozzle ID 90 02. The output liquid pressure in both cases was 1.0 MPa, and the flow rate was between 1.42 and 1.46 L min^{-1}. The droplet size after the application of EPNs suspension was 400 µm, while after the application of thiametoxam the same parameter was 300 µm. In 2008, the first application of the EPNs and the insecticide was performed (22 July). Weekly application (1, 2 weeks AFA) of the nematodes was performed with the same equipment as in 2007, similar to the application of the insecticide 2 weeks AFA. Later occurrence of GWF adults in 2008 was the main reason for reducing nematode application in 2008 comparing with 2007.

After application of EPN, the confirmation that GWF adults were killed by the nematodes was done by collecting dead adults on the surface of cucumber leaves. They were put into petri dishes in the dark (room conditions). The presence of the new population of *S. feltiae* in the body of GWT adults and in their vicinity was used as confirmation that the adults had actually been killed by nematodes (Trdan et al. 2008).

No pests, other than the GWF studied here, were seen on the cucumbers to any substantial degree during the course of study. The only other infection of note on cucumbers was powdery mildew *Sphaerotheca fuliginea* (Schlecht.) Pollacci, which was controlled efficiently in the early stages of infection with spraying twice (2 and 3 weeks AFA) with the fungicide azoxystrobin (250 g L^{-1}; 0.075% Quadris; manufacturer: Syngenta Limited AG, Fernhurst, UK; supplier: Syngenta Agro d.o.o., Ljubljana, Slovenia). In both years the fungicide was applied to all experimental areas.

Observations and evaluations

Evaluations were taken at 3 time-points in 2007 (3, 5, and 7 weeks AFA) and 2 time-points in 2008 (1 and 2 weeks AFA) during the growing season. At each time-point, 3 randomly selected plants of about the same height in each sub-plot were assessed for the number of GWF adults. Three leaves (lower, middle, and upper part) from each chosen plant were evaluated in the morning (at about 0700), when adults were stable due to relatively low temperature

(Bellows et al. 1988).

Cucumber fruits were harvested when their diameters were 3-4 cm. In 2007 harvesting began 3 weeks after the first application and continued up to 5 weeks after the first application, when all remaining marketable fruit was harvested. The yield was classified into 3 groups according to harvest time (up to 3 weeks AFA, between 3 and 5 weeks AFA, and 5 weeks AFA). In 2008 harvesting began 1 week AFA and continued up to 2 weeks AFA, when all remaining marketable fruit was harvested. The yield was classified into 2 groups according to harvest time (up to 1 week AFA and 2 weeks AFA). The cucumber yield was determined in 2 ways: 1) mass of fruits per plant, and 2) number of fruits per plant (Trdan et al. 2007).

Data analyses

Differences in number of fruits, and mass of fruits with 3 different pest treatments (EPN, insecticide, and control) and between 4 different growth substrates were analyzed individually at each time of fruit picking using ANOVA. Prior to analysis, each variable was tested for homogeneity of variance, and those data found to be non-homogeneous were transformed to log(*Y*) before ANOVA. Significant differences ($P \leq 0.05$) between mean values were identified using Student-Newman-Keuls's multiple range test. Data of the number of GWF adults on the cucumber leaves had a nonparametric distribution and so were analyzed using the Kruskal-Wallis test. As in the case of the first 2 parameters, means were determined to be significantly different when there was no overlap of the 95% confidence intervals. All statistical analyses were done using Statgraphics Plus for Windows 4.0 (Statistical Graphics Corp., Manugistics, Inc.). The data are presented as untransformated means ± SE.

Results

Number of GWF on cucumbers

In both years the date of assessment (2007: F = 86.62, df = 2, 179, P < 0.0001; 2008: F = 5.59, df = 1, 70, P < 0.0001), type of the substrate (2007: F = 14.37, df = 3, 179, P < 0.0001; 2008: F = 2.71, df = 3, 70, P < 0.0414), control method (2007: F = 134.72, df = 2, 179, P < 0.0001; 2008: F = 10.09, df = 2, 70, P < 0.0001), and interaction between type of substrate and control method (2007: F = 6.42, df = 6, 179, P < 0.0001; 2008: F = 2.35, df = 6, 70, P = 0.0396) had significant influence on the mean number of *T. vaporariorum* adults per leaf. Significantly, the lowest number of the GWF adults per leaf in 2007 (3 weeks AFA: 3.00 ± 0.47 [F = 17.11, df = 3, 59, P < 0.0001]; 5 weeks AFA: 25.89 ± 4.24 [F = 25.23, df = 3, 59, P < 0.0001), and in 2008 (1 week AFA: 34.33 ± 23.14 [F = 2.14, df = 3, 24, P = 0.0121]; 2 weeks AFA: 32.00 ± 14.1 [F = 0.99, df = 3, 24, P = 0.0412]) was confirmed on the cucumbers grown in expanded perlite (Figure 1a, 1b). Additionally in 2008, the number of the GWF adults in this treatment did not differ significantly with the treatments vermiculite (1 week AFA: 38.56 ± 10.66; 2 weeks AFA: 67.67 ± 28.22) and light expanded clay aggregate (43.56 ± 21.41). In 2007 and 2008, there were also no significant differences on the mean number of the GWF adults between vermiculite and light expanded clay aggregate at the same week AFA (2007: from 4.22 ± 0.48 [3 weeks AFA - vermiculite] to 58.78 ± 8.08 [7 weeks AFA - light expanded clay aggregate]; 2008: from 38.56 ± 10.66 [1 week AFA - vermiculite] to 109.22 ± 43.31 [2 weeks AFA - light expanded clay aggregate]). The highest mean number of *T. vaporariorum* adults per leaf was in 2007 confirmed at peat and the values ranged from 23.61 ± 7.71 (3 weeks AFA) to 83.94 ± 15.83 (5 weeks AFA).

The mean number of GWF adults per leaf was significantly influenced with the control methods. In both years, significantly, the highest mean number of the *T. vaporariorum* adults per leaf was confirmed at the control treatment and values ranged from 21.13 ± 5.83 (3 weeks AFA) to 119.17 ± 11.77 (7 weeks AFA) in 2007, and from 89.00 ± 21.62 (1 week AFA) to 128.50 ± 33.00 (2 weeks AFA) in 2008 (Figure 1c, 1d). In 2008, there were no significant differences between the influence of thiamethoxam and EPNs, while a year before the mean number of GWF adults was significantly the lowest in treatment with thiametoxam 3 (2.58 ± 0.38) and 7 weeks (25.64 ± 5.27) AFA.

Mass of cucumbers

In both years, only the control method (2007: F = 10.75, df = 2, 234, P < 0.0001; 2008: F = 39.28, df = 2, 313, P < 0.0001) had significant influence on the

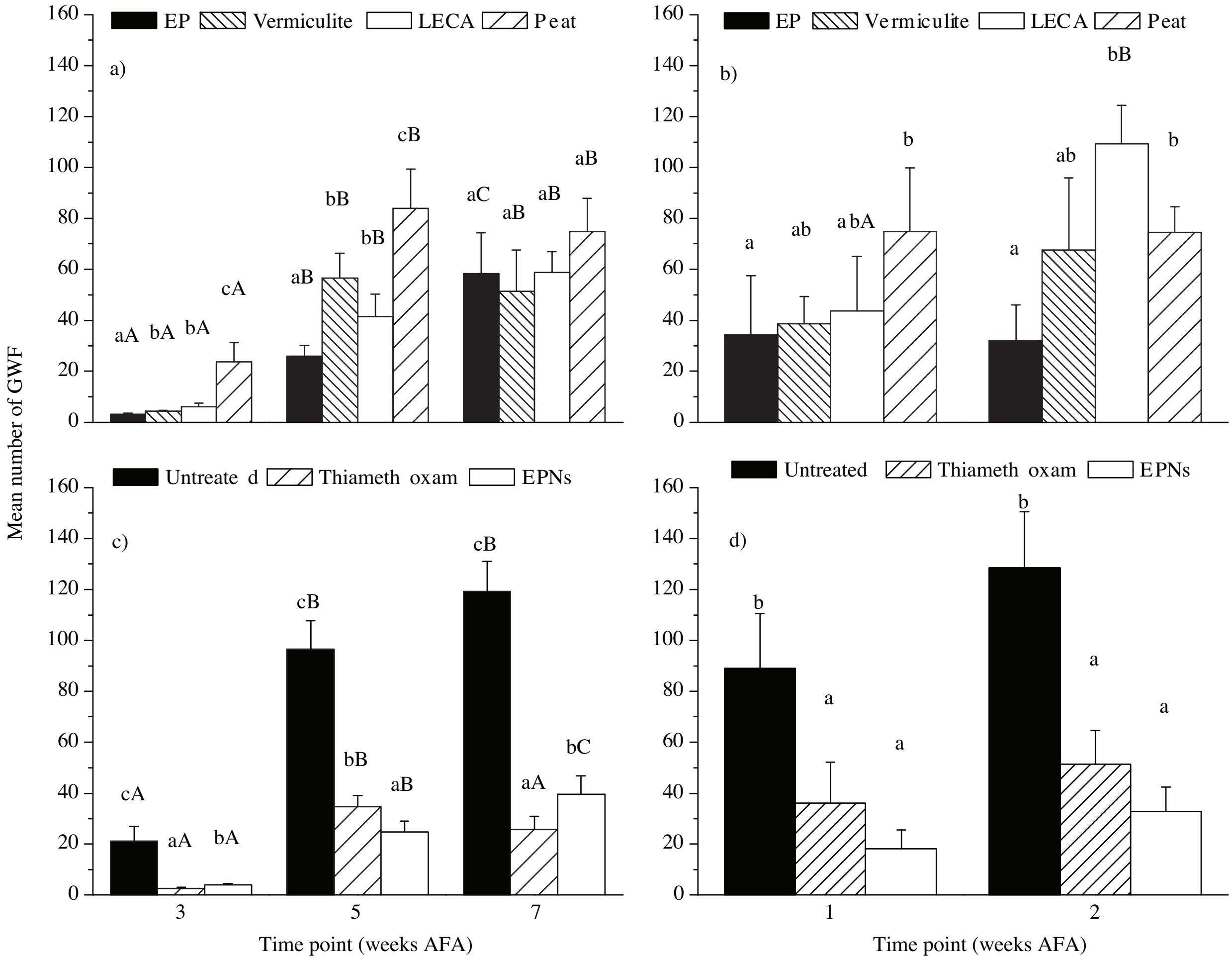

Figure 1. Mean number of GWF adults per plant in 2007 (a, c) and 2008 (b, d) at different growth substrates (a, b) (EP - expanded perlite, LECA - light expanded clay aggregate) and control methods (c, d). Different small letters indicate significant differences (P > 0.05) within AFA (after first application) and different capital letters indicate significant differences between growth substrates and control method according to Student-Newman-Keuls's multiple range test.

mass of cucumbers per plant. In 2007, the type of substrate had no significant influence on the yield (g) of cucumbers between 3 and 5 weeks AFA (F = 0.09; df = 3, 21; P = 0.9647) and the values ranged from 279.43 ± 17.73 [expanded perlite] to 294.5 ± 15.36 [vermiculite]), and between 5 and 7 weeks AFA (F = 1.07; df = 3, 101; P = 0.3676), when the values ranged from 282.86 ± 20.58 [vermiculite] to 322.11 ± 34.29 [peat] (Figure 2a). In 2007 and 2008, the lowest mean mass (g) of fruits per plant was recorded 3 weeks AFA (217.60 ± 10.75) and 1 week AFA (237.62 ± 9.47) on cucumbers grown on expanded perlite, respectively). In 2008, the highest mean mass (g) of cucumbers per plant was recorded on vermiculite 1 week AFA (295.56 ± 8.75); however, between vermiculite and light expanded clay aggregate in both taken time-points there were no significant differences (Figure 2b).

The lowest mean mass (g) of cucumbers per plant was confirmed at the control treatment and the values ranged from 229.91 ± 12.92 (3 weeks AFA) to 254.35 ± 11.83 (between 3 to 5 AFA) in 2007 and from 211.51 ± 6.46 (2 weeks AFA) to 228.48 ± 9.47 (1 week AFA) in 2008 (Figure 2c, 2d). In 2008, there were no significant differences (F = 39.28, df = 2, 313, P < 0.0001) between thiamethoxam and EPNs

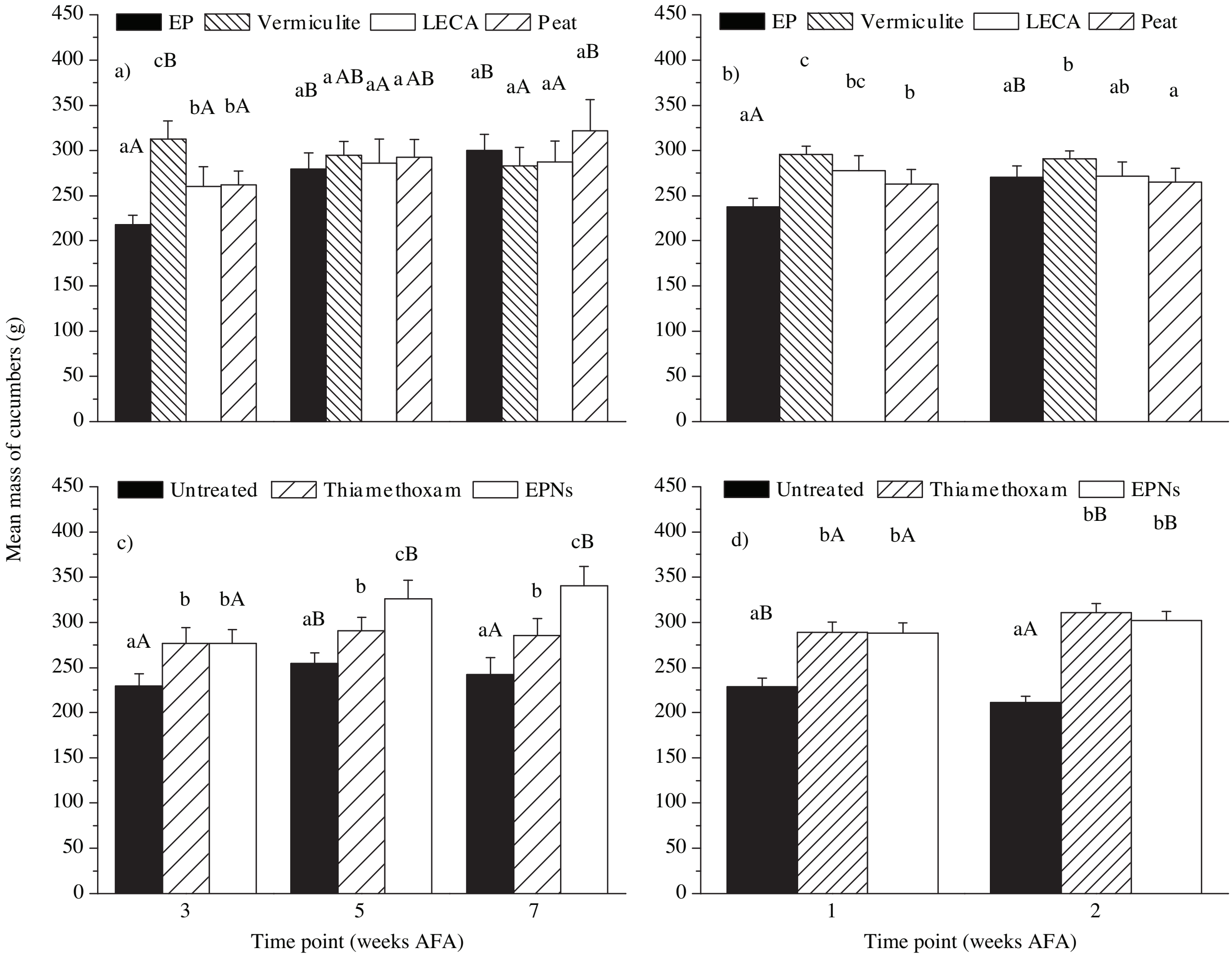

Figure 2. Mean mass of cucumbers per plant (g) in 2007 (a, b) and 2008 (c, d) at different growth substrates (a, b) (EP - expanded perlite, LECA - light expanded clay aggregate) and control methods (c, d). Different small letters indicate significant differences (P > 0.05) within AFA (after first application) and different capital letters indicate significant differences between growth substrates and control method according to Student-Newman-Keuls's multiple range test.

treatment and the values ranged from 288.10 ± 11.13 (EPNs) to 310.69 ± 10.27 (thiamethoxam). In 2007, (F = 2.46, df = 2, 234, P = 0.0087) the highest mean mass (g) of cucumbers was recorded 7 weeks AFA with EPNs treatment (340.59 ± 21.38).

Mean number of cucumbers

In both years, only the type of substrate (2007: F = 3.17, df = 3, 65, P = 0.0299; 2008: F = 3.64, df = 3, 81, P = 0.0162) had significant influence on the mean number of cucumbers per plant. In 2007, the type of substrate had no significant influence on the mean number of cucumber fruits between 3 and 5 weeks AFA (F = 0.8174; df = 3, 21; P = 0.9647), and the values ranged from 2.29 ± 0.36 (light expanded clay aggregate) to 2.89 ± 0.54 (vermiculite) (Figure 3a). In the same year 3 weeks AFA (2.83 ± 0.40) and 5 weeks AFA (1.86 ± 0.34), the lowest mean number of cucumber fruits was also confirmed on the light expanded clay aggregate, which was also the case in 2008 (1 week AFA: 2.63 ± 0.42; 2 weeks AFA: 2.67 ± 0.29). In the first week AFA in 2008, the mean number of cucumbers per plant did not significantly differ (F = 3.64, df = 3, 81, P = 0.0162) between expanded perlite, vermiculite, and peat (Figure 3b).

The values ranged from 3.18 ± 0.35 (thiamethoxam, 1 week AFA) to 3.67 ± 0.26 (EPNs, 2 weeks AFA). In 2007, the control treatment influenced the number of cucumbers per plant and the values ranged from

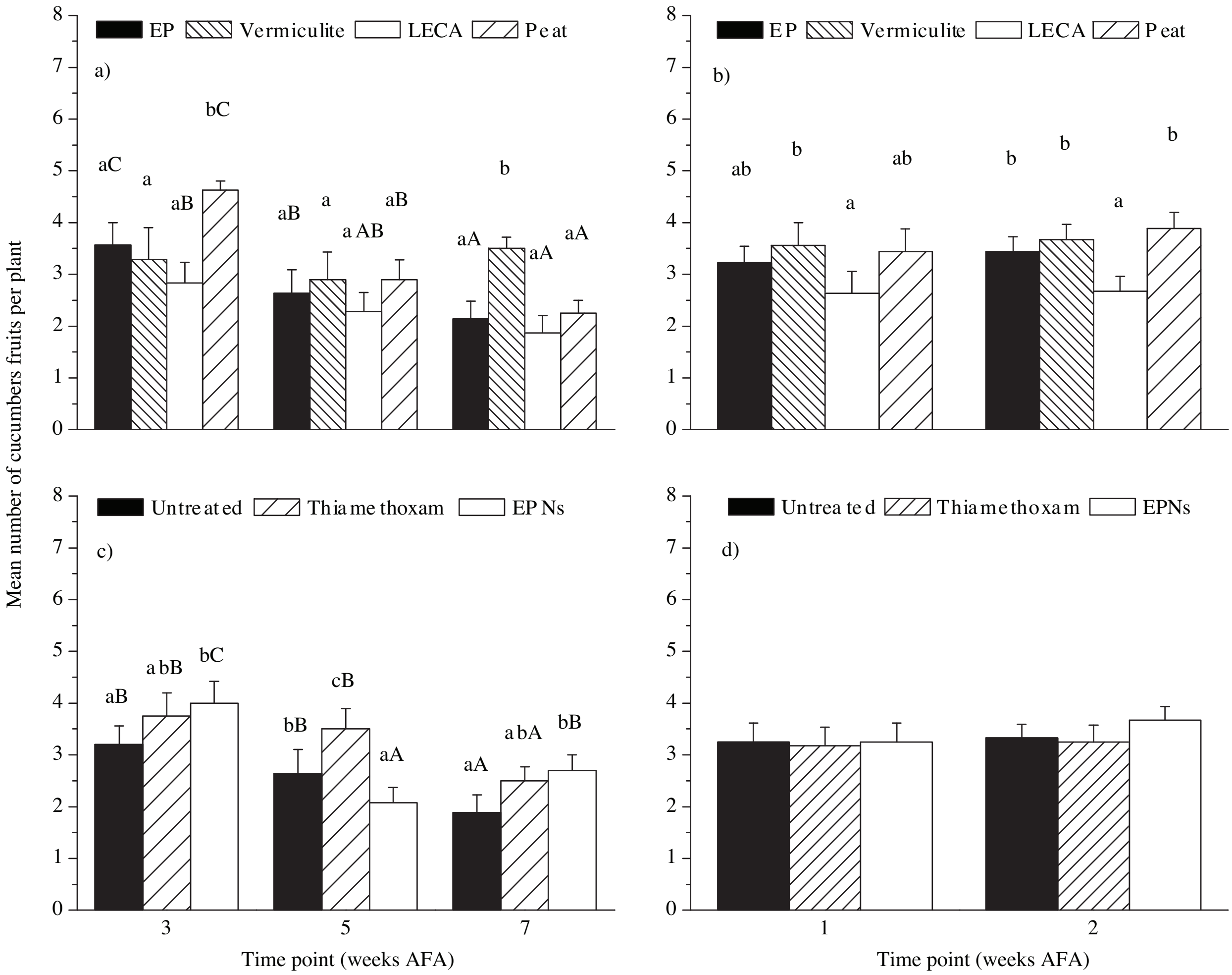

Figure 3. Mean number of cucumbers fruits per plant in 2007 (a, b) and 2008 (c, d) at different growth substrates (a, b) (EP - expanded perlite, LECA - light expanded clay aggregate) and control methods (c, d). Different small letters indicate significant differences (P > 0.05) within AFA (after first application) and different capital letters indicate significant differences between growth substrates and control method according to Student-Newman-Keuls's multiple range test.

1.88 ± 0.35 (untreated, 7 weeks AFA) to 4.00 ± 0.42 (EPNs, 3 weeks AFA) (Figure 3c). For 3 (F = 2.09, df = 2, 16, P = 0.0156) and 7 weeks (F = 0.84, df = 2, 16, P = 0.0451) AFA, the plants treated with EPNs (4.00 ± 0.42, and 2.70 ± 0.30) and thiametoxam (3.75 ± 0.45, and 2.50 ± 0.27) gave significantly the highest number of fruits per plant, while 5 weeks AFA significantly (F = 2.92, df = 2, 16, P = 0.0076) the highest yield (3.50 ± 0.40) was achieved with the use of thiametoxam. In 2008, different control methods did not have an influence on the mean number of cucumbers fruits per plant (Figure 3d).

Discussion

In the present study, adults of GWF showed sensitivity to the attack of the *S. feltiae* and to insecticide thiamethoxam under glasshouse conditions. We attribute these results to our multifold application of nematodes, since it is known that, in general, the survival of the infective juveniles on the leaf decreased with the exposure time (Jin et al., 2004). In a similar study, a higher concentration of EPNs was also seen to produce a greater mortality rate of western flower thrips (Ebssa et al. 2004).

Qui et al. (2008) evaluated the potential for using infective juveniles of the *Steinernema feltiae* to control the sweetpotato whitefly *Bemisia tabaci* B biotype on cucumber, hibiscus, and collard, under greenhouse conditions. The mortality of *B. tabaci* nymphs increased by 20% on cucumber plants when *S. feltiae* concentration increased from 5000 to 15,000 infective juveniles mL^{-1}. In related research by Cuthbertson et al. (2003), the compatibility of *S. feltiae* with a different chemical insecticides against the sweetpotato whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae), was investigated. The authors concluded that nematodes in combination with imidacloprid gave significantly higher mortality of *B. tabaci* larvae.

Desirable assets such as ease of mass production and efficacy and safety to nontarget organisms have evoked commercial interest in EPNs (Parwinder and Georgis 1994). From a praxis-orientated point of view, high doses probably negatively affect the practical application of EPN formulations, due to cost and formulation stability (Athanassiou et al. 2010; Laznik et al. 2010). However, other studies show that, for some species, lower doses are required (Ramos-Rodríguez et al. 2006).

Thiamethoxam is a chloronicotinyl insecticide that acts as a nicotin acetylcholine receptor agonist and is widely used to control homopteran pests (Leicht 1993; Elbert et al. 1998). In a related research (Bi et al. 2002), it is reported that it caused only 67% mortality of GWF nymphs. Elbert et al. (1998) however suggested that imidacloprid can control whiteflies resistant to conventional insecticides and soil treatments have no adverse effects on beneficial organisms, and so it fits well into resistant management strategies and can be considered an important component of integrated whitefly management.

We also determined the effect of the feeding of GWF adults on mean mass of cucumbers. Different control strategies had greater influence on the mean mass of cucumbers than type of the growth substrate. In the control treatment, where we found the highest number of GWF adults, the mean mass of cucumbers in both observed years was the lowest. Results from 2007 even proved that the yield, where the control strategy was performed with the use of EPNs, was the greatest. In some related research (Johnson et al. 1992), the authors concluded that the feeding of the immature GWF had great influence on the tomato yield, which was also determined in a study by Trdan et al. (2007). The type of the growth substrate did not have a significant influence on the mean mass of the cucumbers in 2007, but in 2008 we confirmed the highest mean mass of cucumbers on plants, grown in vermiculite, where the lowest number of the GWF adults was also found. In a similar study (Szwejda and Nawrocka 1999), the tomato leafminer (*Liriomyza bryoniae*) caused significantly greater damage to tomato plants grown on peat. It is probable that the type of growth substrate affected the susceptibility of tomato plants, as both tomato and cucumber are equally susceptible to leafminers (Tokumaru and Abe 2005).

In our experiment, light expanded clay aggregate appeared to be a less appropriate growth substrate, as cucumbers grown on this type of substrate produced the lowest number of fruits per plant. Similar conclusions are also reported by Trdan et al. (2007) in research regarding the control of western flower thrips on cucumbers. In a similar research with different growth substrates (coir, sawdust, rockwool, perlite, and cucumber mix), no differences in the number of fruits per plant and average fruit mass were observed (Parks et al. 2004). Similar conclusions were also reached in a study exploring the influences of medium perlite, coarse perlite, and pine bark on cucumber yield (Cantliffe et al. 2003). Although it is difficult to compare results across studies, it appears as though there is generally not a large influence of substrate type on the number or mass of cucumber fruits. However, our results indicate that, in conditions similar to those of our study, the use of light expanded clay aggregate is not advisable, as it was seen to produce poorer growth results. Our data indicated that both vermiculite and peat are suitable for cucumber production, as previously demonstrated (Sawan et al. 1999; Trdan et al. 2007).

Chemical control is still an important component of integrated pest management systems (Ganesan et al. 2007). GWF have already developed resistance to some conventional insecticides as acephate and dicrotophos in California (Omer et al. 1992). Introducing and alternating these chemicals on cucumbers in a defined way will be strategic to combat the potential risk of GWF resistance to these insecticides. On the other hand, the results of some research recommended the use of the substances of non-insecticidal origin – for example the household soaps and detergents – against GWF adults in glasshouse conditions (Arias et al. 2006). Furthermore, for the control of GWF on cucumber crops, biological control with EPN suspension was seen to be equally as effective as the currently widely-used and highly-recommended chemical insecticide thiamethoxam. Thus, we think that, with proper optimization, the application of these biological agents represents a very promising alternative to the current chemical control methods.

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