Pedobiologia 50 (2006) 23–29

Available online at www.sciencedirect.com

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Pedobiologia

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Suppression of tomato hornworm (*Manduca quinquemaculata*) and cucumber beetles (*Acalymma vittatum* and *Diabotrica undecimpunctata*) populations and damage by vermicomposts

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Received 6 June 2005; accepted 5 September 2005

KEYWORDS
Vermicompost;
Arthropod pests;
Cucumber beetles;
Tomato hornworms;
Pest suppression

Summary

The effects of food waste vermicompost on populations of adult striped cucumber beetles (*Acalymma vittatum)* and spotted cucumber beetles (*Diabotrica undecimpunctata*) on cucumbers and larval hornworms on tomatoes (*Manduca quinquemaculata)* were evaluated in both greenhouse and field experiments as well as damage caused. In the field, cucumber and tomato plants were grown, with two different application rates (1.25 and 2.5 t ha^{-1}) of food waste vermicompost or inorganic fertilizer, in a complete randomized block design field experiment. All treatments were balanced for NPK. Field cucumber beetle populations were suppressed significantly on cucumber plants treated with food waste vermicompost at both application rates, compared with those on plants treated only with inorganic fertilizer. In the greenhouse, cucumber and tomato plants were grown in a soil-less medium MetroMix 360 (MM360) substituted with 0%, 20% or 40% food waste vermicompost, and exposed to standardized pest attacks in nylon mesh cages. In the greenhouse, both the 20% and 40% vermicompost substitution rates decreased damage by cucumber beetles to cucumber foliage and hornworms to tomato foliage significantly.

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doi:10.1016/j.pedobi.2005.09.001

Introduction

Vermicomposts are produced from organic wastes through interactions between earthworms and microorganisms, and utilized as plant growth media and soil amendments. They are produced by an aerobic and mesophilic process involving complex interactions between earthworms and microorganisms which stabilizes the organic matter and makes the nutrients it contains available to plants.

It has been shown that various organic amendments, including manures and composts to soil, can suppress pest incidence, populations and damage to plants growing in the amended soils (Chellemi, 2002; Altieri and Nicholls, 2003; Atkinson et al., 2004). The first reports of vermicomposts suppressing arthropod pests were by Edwards and Arancon (2004) and Arancon et al. (2005b) who showed that vermicomposts suppressed cabbage white caterpillar attacks on cabbages. Theses authors also reported significant suppression of mealy bug attacks (Pseudococcus) on cucumbers and tomatoes, two-spotted spider mite attacks (*Tetranychus urticae*) on bush beans and eggplants and attacks by aphids (*Myzuz persicae*) on cabbages by low application rates of food waste vermicomposts (Arancon et al., 2005a, b).

The experiments reported here aimed to evaluate the effects of low application rates of food waste vermicomposts in the field, or substitutions of vermicomposts into soil-less bedding plant growth medium (MM360) in the greenhouse, on cucumber beetle and hornworm populations. They will also document resulting damage to cucumber and tomato plants, compared with populations of these pests and damage to plants grown with only inorganic fertilizers, in the greenhouse and field, when all of the nutrient inputs were balanced for NP and K.

Materials and methods

Field experiments

The experimental field site was located at the Ohio State University Waterman Research Farm in Columbus, OH. The soil is Kokomo silty loam and the mean rainfall amount is 107.3 cm year^{-1}. The tomato and cucumber field experiments, which were laid out on separate blocks of plots, used randomized complete block designs, with 21 plots each receiving one of three nutrient treatments, replicated seven times. There were two different food waste vermicompost application rates: (2.5 and 1.25 t ha^{-1}) compared with a recommended application rate of inorganic fertilizer 100–90–100 NPK kg ha^{-1}. All of the vermicompost treatments were supplemented with inorganic fertilizer, to balance the NPK rates with those applied to the inorganic fertilizer plots, so that all plots were balanced initially, as far as possible, for nutrient inputs. Each tomato field plot (1.5 m wide, 6 m long) was covered with plastic mulch and 20 tomato seedlings were transplanted at 30 cm interplant spacing in single rows on 1.5 m centers. The tomato seedlings were grown using commercial practices in the greenhouse for 6 weeks, then were transplanted to the field on 20 June 2004 and the cucumbers were seeded directly into the plots 1 day later (21 June 2004) in plots of the same size. Each cucumber plot consisted of 24 hills of cucumbers seeded at a 30 cm interplant spacing in double rows. In both experiments, the treatment plots were separated by untreated rows of plants. Crops were irrigated as necessary using irrigation water tapes placed in the rows under a black plastic mulch.

Foliage in the field cucumber plots was scouted once a week, to assess populations of cucumber beetles, (the striped cucumber beetle, *Acalymma vittatum* (Fab.) and the spotted cucumber beetle, *Diabrotica undecimpunctata hovardii* (Barber) (Coleoptera: Chrysomelidae), on each sampling date between 14 July and 18 August 2004. Four cucumber plants were selected at random in each plot, and all of the leaves and stems were examined systematically for occurrence of the beetles, and their numbers and distributions were recorded. The incidence and numbers of tomato hornworm caterpillars, *Manduca quinquemaculata* (Haworth) (Lepidoptera: Sphingidae) on the field tomatoes were assessed at harvest time. Four whole tomato plant samples were harvested and assessments of damage from each treatment plot were made. Tomato fruits were separated from the foliage and inspected for damage. Fruits that had visible damage by hornworm caterpillars were segregated, counted, and amounts of damage recorded. Yields were also measured.

Greenhouse experiments

Tomatoes and cucumbers were grown in a soil-less commercial greenhouse container bedding plant medium, Metro-Mix (MM360) (Scotts, Marysville, OH) with different applications rates of food waste vermicompost substituted into the MM360. MM360 is a preparation of vermiculite, Canadian sphagnum peat moss, bark ash and sand and has a starter nutrient fertilizer in its formulation. Mixtures were 0%, 20% or 40% of commercially produced food waste vermicompost (Oregon Soil Corporation, Portland, Oregon) in 100%, 80%, or 60% of MM360. The food waste vermicompost used contained 1.3% N, 2.7% P and 9.2% K and additional nutrients were added by watering plants with Peters Nutrient Solution three times weekly.

Either two tomato or two cucumber seeds were sown into each 10 cm diameter pot, containing, 100% MM360, 80% MM360 mixed with 20% vermicompost, or 60% MM360 mixed with 40% vermicompost. The seedlings were thinned to one per pot 7 days after transplanting. The experimental vermicompost/MM360 and pest infestation treatments were: (i) plants grown in MM360 soil-less plant growth medium and exposed to pests; (ii) plants grown in a 20% food waste vermicompost and 80% MM360 mixture and exposed to pests; (iii) plants grown in a 40% food waste vermicompost and 60% MM360 mixture and exposed to pests. A second set of identical treatments, (i, ii, and iii) were grown, caged, and not exposed to pests to allow assessment of extent of pest damage.

Each experimental treatment involved 10 replicate pots for each plant species, confined in a single mesh (0.2 mm aperture) cage $40 \times 40 \times 40$ cm. One of the three experimental pest treatments outlined above was applied to each cage and replicated ten times with a total of 30 pots (3 treatments $\times$ 10 replicates) per insect pest species. The seedlings were raised in an insect-free environment for 4 weeks. Batches of caged plants were placed on capillary mats for ease of watering and nutrient addition under the mesh cages. The control plants, without any insect infestations, were placed in similar cages to use as a basis for plant foliar loss calculations to enable comparisons to be made with plants artificially infested with pests.

The adult striped cucumber beetles used in the greenhouse experiments were collected from the field. The hornworms were obtained as eggs from Carolina Biological Supply Co., NC, USA and hatched on plants. In the 5th week of growth, experimental groups of plants were laid out in a completely randomized pattern (CRD) in cages on capillary mats on greenhouse benches. Four adult striped cucumber beetles (*A. vittatum)* were released into each cage to assess damage by this pest. The numbers of beetles remained constant over 2 days and none died in any of the cages, so instead of using population counts to assess the effects of the vermicomposts, damage assessments were made, since the beetles fed voraciously on the foliage leaving little leaf tissue remaining by the end of the experiment. The damage was assessed as amounts of leaf area remaining after 2 days of cucumber beetle feeding. The damage ratings were assessed based on a scale from 0 (no damage) to 4 (severe damage). In a similar greenhouse experiment, four 1-week-old hornworm caterpillars (*M. quinquemaculata)* were used in each cage instead of cucumber beetles. The hornworm damage measurements also had to be made over short periods of time of up to 2 days, due to the voracious feeding on the tomato foliage by the hornworm caterpillars.

A one-way analysis of variance (ANOVA) was used to test treatment differences statistically. Group means were compared and separated for significant differences ($P \leqslant 0.05$) by Duncan's Multiple-Range Test.

Results

In the field experiments, the seasonal populations of both striped cucumber beetles (Fig. 1) and spotted cucumber beetles (Fig. 2) and the total populations of cucumber beetles (Fig. 3) were significantly lower ($P \leqslant 0.05$) on cucumber plants grown with vermicompost at both application rates, compared with those on plants grown with only inorganic fertilizer. Populations of both species of cucumber beetle did not differ significantly between plots that received 2.5 or 1.25 t ha^{-1} vermicomposts, but were significantly lower in all the vermicompost-treated plots than in plots that received only the inorganic fertilizer. The effects of the vermicompost applications on populations of striped cucumber beetles were greater than those

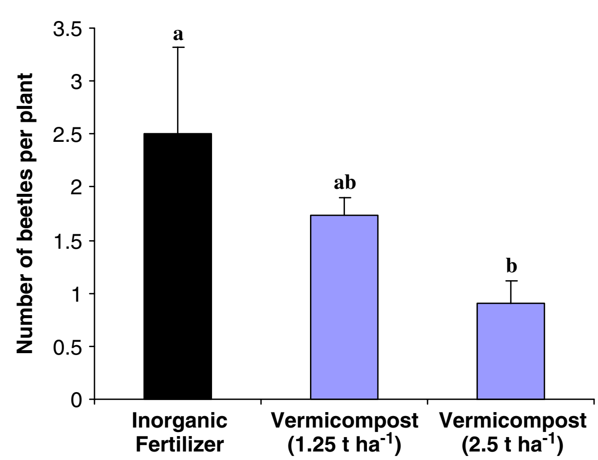

Figure 1. Numbers of striped cucumber beetles, *Acalymma vittatum,* per plant (Means $\pm$ SE) on cucumbers in the field in response to food waste vermicompost applications.

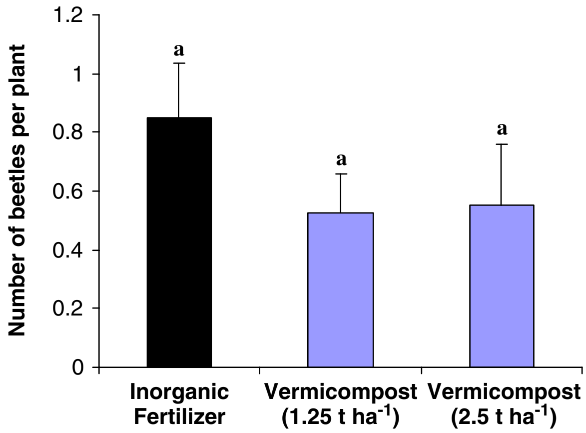

Figure 2. Numbers of spotted cucumber beetles, *Diabrotica undecimpunctata howardi* per plant (Means $\pm$ SE) on cucumbers in the field in response to food waste vermicompost applications.

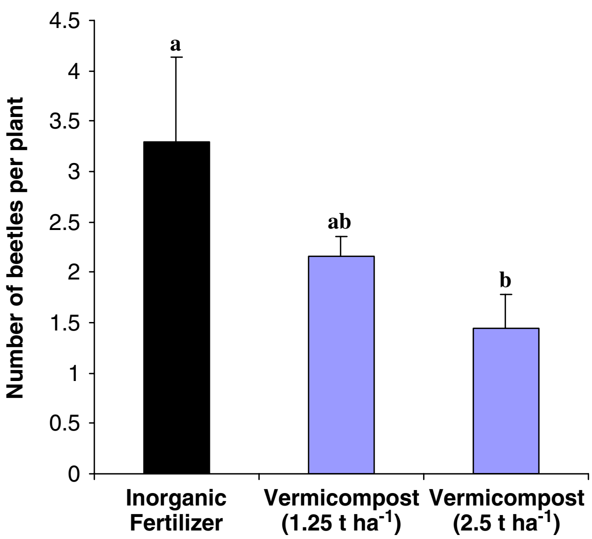

Figure 3. Total numbers of striped and spotted cucumber beetles together (Means $\pm$ SE) on cucumbers in the field in response to food waste vermicompost applications.

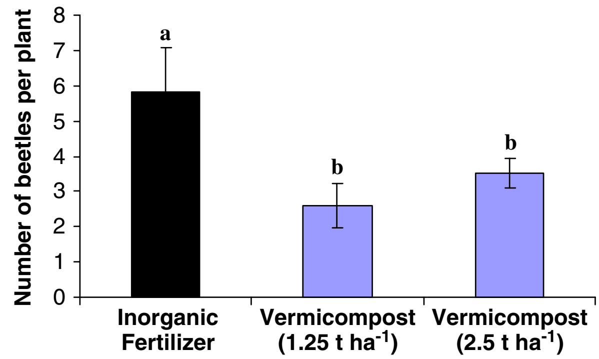

Figure 4. Hornworm caterpillar damage (Mean $\pm$ SE) to tomato fruits in the field, in response to food waste vermicompost applications.

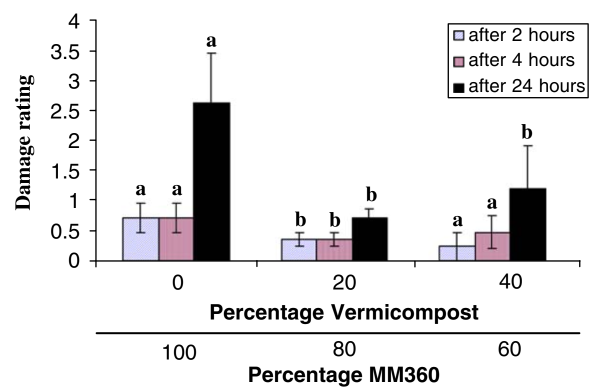

Figure 5. Damage ratings (Means $\pm$ SE) of hornworm caterpillar (*Manduca quinquemaculata*) infestations on tomatoes grown in MM360/food waste vermicompost mixtures with all necessary nutrients in the greenhouse.

on populations of spotted cucumber beetles. Damage by hornworm caterpillars to tomato fruits in the field was decreased significantly by both application rates of food waste vermicomposts, compared to that on plants grown with inorganic fertilizer (Fig. 4).

In greenhouse experiments, the damage caused by hornworm caterpillars was significantly greater ($P \leqslant 0.05$) on tomato plants grown in 100% MM360 than on those grown with 20% or 40% substitutions of vermicomposts although all plants received balanced amounts of nutrients (Fig. 5). In other greenhouse experiments, damage by adult cucumber beetle to cucumber foliage was suppressed significantly by both substitution rates of vermicompost into MetroMix 360, compared with the damage recorded in MetroMix 360 only (Fig. 6).

Discussion

The literature recording suppression of pest arthropods that attack crop plants by chewing the foliage and fruits by vermicomposts is sparse, and published mostly in rather obscure journals. For instance, there have been reports of vermicomposts suppressing attacks of *Spodoptera litura* and *Helicoverpa armigera* on ground nuts in India (Rao, 2001, 2002). In our laboratory, (Arancon et al. (2004, 2005a, b) reported suppression of cabbage white caterpillars (*Pieris brassicae)* on cabbages by vermicomposts.

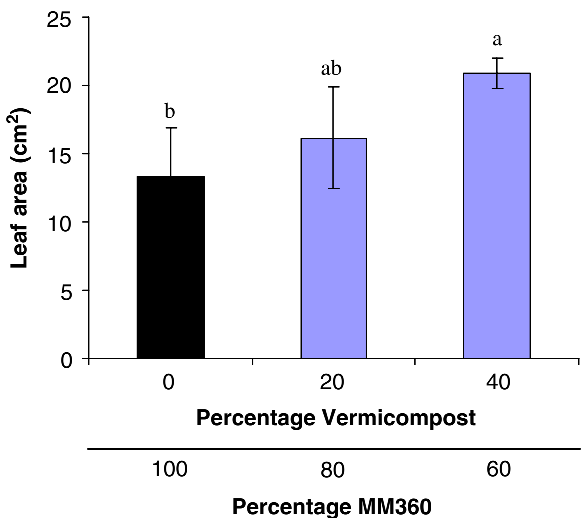

Figure 6. Leaf areas of cucumber seedlings (Means ± SE) after exposure to striped cucumber beetle (*Acalymma vittatum)* infestations in greenhouse cages for 2 days, in response to substitutions of vermicompost into MM360.

The results from the field experiments reported here, demonstrated that populations and damage by cucumber beetles and tomato hornworm caterpillars on tomatoes were much greater on plants grown with only inorganic fertilizer than on those grown with vermicompost applications, when the nutrient inputs (NPK) into all treatments were balanced. These results were supported by the greenhouse experiments that assessed the effects of substitution of a range of concentrations of food waste vermicompost into a soil-less bedding plant growth medium (MM360) on damage by hornworm caterpillars to tomatoes and by striped cucumber beetles to cucumbers also with balanced nutrient inputs. In all these greenhouse experiments foliar losses to these pests were much less in those grown with vermicomposts than on those grown with inorganic fertilizers.

Research on the effects of organic and inorganic fertilizers on pest arthropod populations usually has reported greater numbers of arthropods on plants grown with inorganic fertilizers than on plants grown with organic amendments (Culliney and Pimentel, 1986; Eigenbrode and Pimentel, 1988; Yardim and Edwards, 2003). For instance, Patriquin et al. (1995) reported more aphids (*Aphis fabae)* on plants grown with urea applications than on those grown in organically managed soils. Morales et al. (2001) reported larger populations of aphids (*Rhopalosiphum maidis)* on corn grown with inorganic fertilizers than on corn grown with organic amendments.

It has been suggested that, in general, plants treated with organic amendments are attacked by fewer pests and can resist pest attacks better than plants that are grown with inorganic fertilizers (Phelan et al., 1995). However, the possible mechanisms driving this phenomenon are poorly understood. Various workers have suggested that inorganic N fertilization may decrease plant resistance to insects and increase pest attacked by improving the nutritional quality of the host plants and inhibiting the build up of concentrations of secondary metabolites, which are a source of pest resistance (Fragoyiannis et al., 2001; Herms, 2002). It has been suggested that N may also stimulate the fecundity of insects and attract more individuals for oviposition on host plants grown with inorganic N (Bentz et al., 1995) and also increase insect population growth rates (Jannsson and Smilowitz, 1986). Culliney and Pimentel (1986) postulated that such differences in insect pest populations, in relation to different types of fertilizer inputs, could be due to changes in plant nutritional quality produced in response to different nutritional inputs to the plants. Slowler nutrient release from organic materials (Patriquin et al., 1995) and enhanced nutritional content, for example, with micronutrients and decreased N levels in plants grown with organic amendments (Steffen et al., 1995) could contribute to the resistance of plants to pest attacks. Phelan et al. (1996) suggested that the acceptability of corn to attacks by the corn borer *Ostrinia nubilalis*, could be mediated by the plant's mineral balance, and also by biological buffering characteristics of organically managed soils (Phelan et al., 1995; Phelan, 2004).

Vermicomposts are known to provide a slow, balanced nutritional release pattern to plants, in particular in terms of release of plant available N, soluble K, exchangeable Ca, Mg and P (Edwards and Fletcher, 1988; Edwards, 1998) and vermicomposts have much greater microbial diversity and activity than conventional thermophilic composts, because organic wastes fragmented by earthworms have greater surface area and support higher microbial activity. Morever, microbial activity tends to be suppressed by the high temperatures reached during thermophilic composting.

We suggest that the way in which vermicomposts and similar organic materials may inhibit attack by arthropod pests, on the foliage and fruits of crop plants, is to change the arthropods' feeding responses to types and amounts of N in the foliage. It is known that phenolic substances are distasteful to secondary invertebrate decomposers in soil systems and inhibit the breakdown of dead plant materials (Heath and Edwards, 1964; Edwards and

Heath, 1963). For instance, Asami et al. (2003) reported that total phenolic substances were much higher in strawberries and corn grown organically than in those grown with inorganic fertilizers. It has also been shown that sprays of phenols and phenolic acids extracted from ginkgo plants were as effective in controlling attacks by cotton aphids, vegetable aphids, caterpillars and thrips, as the use if several pesticides approved against these pests. Stevenson et al. (1993) reported inhibition of development of *S. litura* by a phenolic compound from wild ground nut. Summers and Felton (1994) proposed that lepidoptera larval feeding was affected by oxidative stress caused by phenolic compounds.

We hypothesize that the decreases in insect pest numbers and damage on plant grown with vermicomposts, in both our greenhouse and field experiments, could be attributed to some extent to changes in plant nutrition and controlled slower release rates of mineral nutrients in plants through the use of vermicomposts, but more probably by the presence of phenolic compounds in plants grown with vermicomposts.

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