

## Effects of Organic and Synthetic Fertilizer Sources on Pest and Predatory Insects Associated with Tomatoes

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The effects of organic (composted cow manure) and synthetic (NPK) fertilizers on pests (aphids and flea beetles) and predatory arthropods (anthocorids, coccinellids and chrysopids) associated with tomatoes were evaluated in a 2-year randomized complete block field experiment. Our data suggested that the application of either organic or synthetic fertilizers could increase pest populations on tomatoes. However, there were lower populations of aphids on tomatoes grown with the organic fertilizer than on those grown with the synthetic fertilizers in the second year of the experiment, indicating that organic fertilizers may have the potential to reduce pest attacks in the long term. Anthocorid populations were larger on tomato plants with high aphid populations in the synthetic than in the organic fertilizers-treated plots.

KEY WORDS: Synthetic fertilizers; organic fertilizers; plant pests; predatory insects; tomatoes.

### INTRODUCTION

Fertilizers are a major input for increased agricultural productivity. The form of these inputs can influence pest populations in various ways in agroecosystems, depending on the kind of fertilizer used, the crop grown and the insect species present. For instance, alfalfa grown under high soil fertility (phosphorus and potassium) regimes was more favorable to the alfalfa weevil *Hypera postica* (Gyllenhal) and weevil populations increased up to 34%, whereas potato leafhopper *Empoasca fabae* (Harris) populations became 43% greater on alfalfa stands under low soil fertilizer regimes (21). Fertilizers affected aphids only minimally on cabbages (13); they did not affect densities of Russian wheat aphid *Diuraphis noxia* (Mordvilko) on wheat (1), nor did they affect fecundity, longevity and survivorship of melon aphid *Aphis gossypii* Glover on chrysanthemum (4). Damage levels caused by thrips, leafminers, flea beetles, and other insects on tomato plants did not change (15); fruit infestation by *Heliothis armigera* (Hübner) decreased with fertilizer application to tomatoes (14).

There is some evidence that synthetic fertilizers reduce plant resistance to insect pests (10), tend to enhance insect pest populations and can increase the need for insecticide applications (6). For instance, synthetic nitrogen fertilization increased aphid infestations on winter wheat (9). Similarly, numbers of *Aphis fabae* Scopoli increased in faba

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beans when urea was employed (17,18). It has been reported that the survival of the Colorado potato beetle *Leptinotarsa decemlineata* (Say) to adult emergence was enhanced with increasing amounts of NPK (2). Conversely, there are reports in the literature demonstrating that field applications of a range of types of organic matter and traditional thermophilic composts suppress attacks by insect pests (5,7,20), *e.g.* organic fertilizers suppressed corn insect pests such as aphids (16) and the European corn borer (19), and shoot and fruit borer infesting brinjal (22).

Our field experiments aimed to assess some of the ecological effects of organic and synthetic fertilizer inputs on some common pest and predatory arthropod populations in processing tomatoes. We compared a reduced application rate of synthetic fertilizer as well as a full rate of organic fertilizer, because it would have been difficult to grow the crop with a half rate of organic input.

## MATERIALS AND METHODS

**Experimental layout and design** The experimental site was located at the Ohio State University/Ohio Department of Agriculture Demonstration Farm in Reynoldsburg, Ohio (USA), which receives a historical average of 19 cm rainfall during the vegetable growing season. The soil is a medium-textured silty loam type (pH 6.4 and 2.6% organic matter). Each year the field was cultivated in May and appropriate preplant fertilizer and weed management practices were applied.

The experiment was a randomized block design with 16 plots (4.5 m × 4.5 m) involving three fertilizer treatments and an untreated control, each replicated four times. Each plot consisted of three rows of tomato plants with a 1.5-m gap between rows and two 1.5-m buffer gaps between plots. Each plot contained 36 plants grown on raised beds, with 37 cm interplant spacing in rows. The same plots and treatments were used in both 1994 and 1995. Processing tomato plants (Heinz 8704) were grown in both years and the tomato seedlings were transplanted into the field on 15 June in 1994 and 1 June in 1995. Tomatoes were harvested on 9 Sept. in 1994 and 1 Sept. in 1995.

**Fertilizer inputs** There were three different fertilizer treatments plus an untreated control. (i) Full-rate application of synthetic fertilizers: The treatment plots received the Extension Service-recommended application rate of NPK, based on soil tests, in both 1994 and 1995: 2.15 kg of 10:20:20 NPK per plot (20 m<sup>2</sup>) one week before planting and 0.20 kg of 46:0:0 per plot as side dressing at flowering in 1994; and 1.50 kg of 8:32:16 NPK per plot before planting and 0.36 kg of 46:0:0 per plot as side dressing in 1995. (ii) Half-rate application of synthetic fertilizers: In this treatment, plots received 50% of the fertilizers described for the full-rate recommended synthetic fertilizer treatment on the same application dates. (iii) Organic fertilizer: The treatment plots received composted cattle manure (30.80 kg per plot in 1994 and 34.35 kg per plot in 1995) balanced to the full-rate synthetic fertilizers. Manure was applied one week before planting in each year. (iv) An untreated control which received no fertilizer inputs. All the fertilizer amendments (synthetic and organic) used were employed in solid forms. All plots received preplant herbicide applications which included trifluralin (2.37 kg a.i. ha<sup>-1</sup>). No insecticide or fungicide treatments were applied.

**Pest and predator incidence** All of the experimental plots were scouted once a week for pest incidences, from the second week after planting until harvest time. Three tomato

plants were selected at random in each plot on each sampling date and all of the leaves and stems of those plants were examined systematically for aphids (potato aphid *Macrosiphum euphorbiae* (Thomas) and green peach aphid *Myzus persicae* (Sulzer)), flea beetles (*Epitrix* spp.), coccinellids, anthocorids and chrysopid eggs and the numbers of each taxa per plant were recorded. The numbers of aphids were counted on the three uppermost leaflets of the tomato plants in 1994; however, in 1995, the total number of aphids on the whole plant was recorded, because aphid populations were much lower in that year. Data on the numbers of pest taxa and predator taxa counted were analyzed by a two-way ANOVA. Means were separated by Duncan's Multiple Range Test at  $P=0.05$ .

## RESULTS

**Pest incidence** Populations of aphids varied significantly both between the 2 years of study ( $F=46.07$ ,  $df=339.30$ ,  $P<0.01$ ) and among treatments ( $F=5.26$ ,  $df=354.02$ ,  $P<0.01$ ); interaction between years and treatments was significant ( $F=2.71$ ,  $df=329.59$ ,  $P<0.05$ ). Aphids in the experimental plots were significantly ( $P<0.01$ ) more numerous overall in 1994 than in 1995. In 1994, aphid populations differed significantly ( $F=2.01$ ,  $df=463.81$ ,  $P<0.05$ ) among the experimental treatments (Table 1). Populations of aphids were significantly ( $P<0.05$ ) larger (94.4%) in the organic fertilizer-treated plots than in the unfertilized plots. In 1995, the full-rate synthetic fertilizer treatment resulted in significant ( $P<0.01$ ) increases in aphid populations compared with in the other treatment plots.

TABLE 1. Mean seasonal numbers per plant (mean±S.E.) of pests and predators in experimental tomato plots in 1994 and 1995 (Within rows, values followed by a common letter do not differ significantly at  $P<0.05$ )

Taxa	Treatments			
	Full-rate synthetic fertilizer	Half-rate synthetic fertilizer	Organic fertilizer	Control (no fertilizer)
	<u>1994</u>			
Aphids	16.23±3.36ab	14.97±3.36ab	17.41±3.30a	8.95±1.46b
Flea beetles	2.07±0.29a	1.52±0.21ab	2.11±0.26a	1.12±0.17b
Anthocorids	0.52±0.11a	0.37±0.08a	0.57±0.12a	0.28±0.07a
Coccinellids	0.04±0.04a	0.26±0.10a	0.20±0.09a	0.11±0.05a
Chrysopids	0.13±0.06a	0.18±0.07a	0.54±0.25a	0.15±0.06a
	<u>1995</u>			
Aphids	10.95±2.87a	3.21±0.60b	3.35±0.78b	1.26±0.22b
Flea beetles	3.78±0.53a	3.53±0.49a	4.00±0.54a	2.15±0.37b
Anthocorids	0.43±0.08a	0.30±0.09ab	0.38±0.08a	0.15±0.05b
Coccinellids	0.05±0.03a	0.10±0.04a	0.05±0.03a	0.02±0.02a
Chrysopids	0.60±0.28a	0.47±0.25a	0.25±0.10a	0.12±0.06a

The numbers of flea beetles on tomato plants differed significantly between the 2 years ( $F=34.19$ ,  $df=15.59$ ,  $P<0.01$ ) and also among the fertilizer treatments ( $F=4.74$ ,  $df=16.03$ ,  $P<0.01$ ); no significant interaction occurred between years and treatments ( $F=0.87$ ,  $df=15.36$ ,  $P=0.45$ ). Populations of flea beetles were significantly larger in 1995 than in 1994. In 1994, flea beetle populations were significantly ( $P<0.05$ ) larger on tomatoes that received the full rate of synthetic fertilizer (83.9%) and that received the organic fertilizer (98.2%). All of the fertility treatments produced significant ( $P<0.05$ )

increases in flea beetle populations in 1995: respectively, 64.1%, 75.8% and 86% greater in plots receiving the half rate of synthetic fertilizer, the full-rate of synthetic fertilizer, and the organic fertilizer than in the unfertilized control plots.

**Predators** Anthocorids were the most abundant predators in the experimental plots and fertilizer treatments appeared to have significant effects on their numbers ( $F=3.42$ ,  $df=0.43$ ,  $P<0.05$ ) (Table 1). There was no significant interaction between years and treatments with respect to anthocorid populations ( $F=1.07$ ,  $df=0.28$ ,  $P=0.42$ ). There were significantly more anthocorids ( $P<0.05$ ) in plots that received the full rate of synthetic fertilizer (153%) and the organic fertilizer (186.6%) than in those that received no fertilizer in 1995 (Table 1). There were no significant effects of treatments on the numbers of coccinellids ( $F=6.31$ ,  $df=1.28$ ,  $P=0.17$ ) and chrysopid eggs ( $F=1.01$ ,  $df=1.70$ ,  $P=0.38$ ), and no significant interactions between years and treatments for coccinellid beetles ( $F=2.23$ ,  $df=0.17$ ,  $P=0.08$ ) and chrysopid eggs ( $F=1.80$ ,  $df=1.69$ ,  $P=0.14$ ).

## DISCUSSION

The full application rates of synthetic and organic nutrient inputs to the tomato plots increased pest populations significantly and relatively consistently compared with unfertilized controls. Application of half-rates of synthetic fertilizers produced significant increases only in flea beetle populations and only in 1995. It is hypothesized that increases in nitrogen levels in plants can enhance populations of invertebrate herbivores living on them (17,23). Such increases in populations of insect pests on their host-plants in response to higher nitrogen levels can result from various mechanisms, depending on the insect species and host plant. For instance, some changes in nitrogen content in Poinsettias grown with ammonium nitrate stimulated the fecundity of the whitefly *Bemisia tabaci* and attracted more individuals to oviposit on them (3). Nitrogen fertilization may decrease plant resistance to insect pests by improving the nutritional quality of host plants and reducing the secondary metabolite concentrations (10). It was reported that nitrogen applications increased the rate of population growth of green peach aphid on potatoes and that the growth was positively correlated with the concentrations of free amino acids in leaves (12). High levels of nitrogen reduced glycoalkaloid synthesis, which has an inhibitory effect on insect pests of potatoes (8). Barbour *et al.* (2), investigating interactions between fertilizer regimes and host-plant resistance in tomatoes, showed that the survival of Colorado potato beetles to adult emergence increased with larger amounts of fertilizer, and was related to decreases in trichome- and lamellar-based beetle resistance, in response to the improved nutritional quality of the host plant. In addition to increases in the survival rates of Colorado potato beetles from the first instar to adults in tomatoes receiving large amounts of N, nitrogen could also cause significantly faster insect development and increased pupal biomass (11). Nitrogen fertilization can also protract the susceptibility of winter wheat to aphids by lengthening the vegetation period and inhibiting senescence (9).

Some reports have indicated that smaller pest populations occur on plants that receive organic fertilizers, and that such plants can resist pest attacks better than those that receive synthetic fertilizers (5,7). It has been postulated that lower solubility and slower release of nutrients from organic fertilizers could be a reason for smaller pest populations on plants under organic management (17). Edwards and Stinner (6) in their review indicated that organic fertilizers could contribute to decreased pest attacks by increasing pest and predator species diversity and enhancing the activity of pest microbial antagonists.

Coccinellids have been reported to be more numerous on corn treated with organic than with synthetic fertilizer (16). A comparison of pest incidence in organic and conventional chemical fertilizer-treated farms demonstrated that oviposition levels of *Ostrinia nubilalis* (Hübner) were significantly higher on corn (*Zea mays* L.) grown in conventional soil than in organic fertilizer-treated soils. This difference was attributed to biologically buffering characteristics of organically managed soil, because ovipositional preference of the European corn borer was not correlated with plant biomass (19). Similarly, densities of herbivorous insects were found to be lower on collards treated with sewage sludge and manure than with synthetic fertilizers or no fertilizers, although the growth of plants treated with manure and sludge was higher than of those treated with synthetic fertilizers or none (5). Such effects of the organic fertilizer used in our experiment occurred only on aphids in 1995, when the numbers of aphids were significantly lower on plants that received organic fertilizer than the full-rate of synthetic fertilizers. Nevertheless, the effects of organic fertilizers in reducing pest populations may be expressed only in the long term (16,19). Significant differences in aphid populations that occurred between the organic fertilizer-treated tomatoes and those in the full-rate of synthetic fertilizer-treated plots suggest that the organic fertilizer may have led to decreases in aphid numbers. The reductions in aphid populations could not be attributed to the increases in predator populations on tomatoes in the organic fertilizer-treated plots, because the predator populations did not differ significantly between the full-rate synthetic fertilizer-treated and the organic fertilizer-treated plots. However, it seems that both synthetic and organic fertilizer inputs were able to increase flea beetle populations significantly, even when the synthetic fertilizer application rate was reduced to half. Flea beetle populations were significantly higher on plants that received the full-rates of synthetic and organic fertilizers during the 2 years of the study, despite the significant differences between years with respect to flea beetle and other pest numbers.

On the basis of the present results, it could be concluded that both organic and synthetic fertility sources could influence pest and predatory arthropod populations in tomato agroecosystems. Further investigations are needed to elucidate the causal mechanism(s) of the influence of different forms of nutrients. These should focus on interactions between pests and predators, and analyses of physiological, biochemical and morphological changes in the host plants, microbial antagonistic activity in soil, and overall biodiversity of the agroecosystem. Knowledge of changes in environmental conditions in response to use of fertilizers could be utilized effectively in plant protection in both IPM and organic farming contexts.

#### REFERENCES

1. Archer, T.L., Bynum, E.D. Jr., Onken, A.B. and Wendt, C.W. (1995) Influence of water and nitrogen fertilizer on biology of the Russian wheat aphid (Homoptera: Aphididae) on wheat. *Crop Prot.* 14:165-169.
2. Barbour, J.D., Farrar, R.R. and Kennedy, G.G. (1991) Interaction of fertilizer regime with host-plant resistance in tomato. *Entomol. Exp. Appl.* 60:289-300.
3. Bentz, J.-A., Reeves, J. III, Barbosa, P. and Francis, B. (1995) Nitrogen fertilizer effect on selection, acceptance, and suitability of *Euphorbia pulcherrima* (Euphorbiaceae) as a host plant to *Bemisia tabaci* (Homoptera: Aleyrodidae). *Environ. Entomol.* 24:40-45.
4. Bethke, J.A., Redak, R.A. and Schuch, U.K. (1998) Melon aphid performance on chrysanthemum as mediated by cultivar, and differential levels of fertilization and irrigation. *Entomol. Exp. Appl.* 88:41-47.
5. Culliney, T.W. and Pimentel, D. (1986) Ecological effects of organic agricultural practices on insect populations. *Agric. Ecosyst. Environ.* 15:253-256.

6. Edwards, C.A. and Stinner, B.R. (1990) The use of innovative agricultural practices in a farm systems context for pest control in the 1990s. *Brighton Crop Protection Conf. – Pests and Diseases* vol. 7C-3, pp. 679-684.
7. Eigenbrode, S.D. and Pimentel, D. (1988) Effects of manure and chemical fertilizers on insect pest populations on collards. *Agric. Ecosyst. Environ.* 20:109-125.
8. Fragoiannis, D.A., McKinlay, R.G. and D’Mello, J.P.F. (2001) Interactions of aphid herbivory and nitrogen availability on the total foliar glycoalkaloid content of potato plants. *J. Chem. Ecol.* 27:1749-1762.
9. Hasken, K.-H. and Poehling, H.-M. (1995) Effects of different intensities of fertilisers and pesticides on aphids and aphid predators in winter wheat. *Agric. Ecosyst. Environ.* 52:45-50.
10. Herms, D.A. (2002) Effects of fertilization on insect resistance of woody ornamental plants: Reassessing an entrenched paradigm. *Environ. Entomol.* 31:923-933.
11. Hunt, D.W.A., Drudy, C.G. and Maw, H.E.L. (1992) Influence of nitrogen on the performance of Colorado potato beetle (Coleoptera: Chrysomelidae) on tomato. *Environ. Entomol.* 21:817-821.
12. Jansson, R.K. and Smilowitz, Z. (1986) Influence of nitrogen on population parameters of potato insects: Abundance, population growth and within-plant distribution of the green peach aphid, *Myzus persicae* (Homoptera: Aphididae). *Environ. Entomol.* 15:49-55.
13. Kalule, T. and Wright, D.J. (2002) Tritrophic interactions between cabbage cultivars with different resistance and fertilizer levels, cruciferous aphids and parasitoids under field conditions. *Bull. Entomol. Res.* 92:61-69.
14. Kasyap, R.K. and Batra, B.R. (1987) Influence of some crop management practices on the incidence of *Heliothis armigera* (Hübner) and yield of tomato (*Lycopersicon esculentum* Mill.) in India. *Trop. Pest Manage.* 33:166-169.
15. Letourneau, D.K., Drinkwater, L. and Shennan, C. (1996) Effects of soil management on crop nitrogen and insect damage in organic vs. conventional tomato fields. *Agric. Ecosyst. Environ.* 57:179-187.
16. Morales, H., Perfecto, I. and Ferguson, B. (2001) Traditional fertilization and its effect on corn insect populations in the Guatemalan highlands. *Agric. Ecosyst. Environ.* 84:145-155.
17. Patriquin, D.G., Baines, D. and Abboud, A. (1995) Diseases, pests and soil fertility. in: Cook, H.F. and Lee, H.C. [Eds.] *Soil Management in Sustainable Agriculture*. Wye College Press, Wye, UK. pp. 161-174.
18. Patriquin, D.G., Baines, D., Lewis, J. and MacDougall, A. (1988) Aphid infestations of fababeans on an organic farm in relation to weeds, intercrops and added nitrogen. *Agric. Ecosyst. Environ.* 20:279-288.
19. Phelan, P.L., Mason, J.F. and Stinner, B.R. (1995) Soil-fertility management and host preference by European corn borer, *Ostrinia nubilalis* (Hübner), on *Zea mays* L.: A comparison of organic and conventional chemical farming. *Agric. Ecosyst. Environ.* 56:1-8.
20. Rao, K.R. (2002) Induced host plant resistance in the management of sucking insect pests of groundnut. *Ann. Plant Prot. Sci.* 10:45-50.
21. Shaw, M.C., Wilson, M.C. and Rhykerd, C.L. (1986) Influence of phosphorus and potassium fertilization on damage to alfalfa, *Medicago sativa* L., by the alfalfa weevil, *Hypera postica* (Gyllenhal) and potato leafhopper, *Empoasca fabae* (Harris). *Crop Prot.* 5:245-249.
22. Sudhakar, K., Punnaiah, K.C. and Krishnayya, P.V. (1998) Influence of organic and inorganic fertilizers and certain insecticides on the incidence of shoot and fruit borer, *Leucinodes orbonalis* Guen. infesting brinjal. *J. Entomol. Res.* 22:283-286.
23. White, T.C.R. (1984) The abundance of invertebrate herbivores in relation to the availability of nitrogen in stressed food plants. *Oecologia* 63:90-105.