Effects of Fertilizers on Suppression of Black Cutworm (*Agrotis ipsilon*) Damage with *Steinernema carpocapsae*[1]

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Abstract: The ability of *Steinernema carpocapsae* to reduce damage to seedling corn by the black cutworm, *Agrotis ipsilon,* in soil amended with three fertilizers (fresh cow manure, composted manure, and urea) was determined. Total nitrogen was standardized among the fertilizers at 280 kg/ha and 560 kg/ha. Black cutworm damage was assessed by the percentage of cut corn plants in small field plots. Relative to a control (no nematodes), nematode applications resulted in reduced black cutworm damage in all treatments except in the higher rate of fresh manure. Black cutworm damage in nematode-treated plots was greater in plots with fresh manure than in plots without fertilizer. Other amendments (urea and composted manure) did not have a detrimental effect on suppression of the black cutworm by *S. carpocapsae.*

Key words: *Agrotis ipsilon,* black cutworm, entomopathogenic nematodes, fertilizer, manure, nematode, *Steinernema carpocapsae.*

The black cutworm, *Agrotis ipsilon* (Hufnagel), is a pest of seedling corn in Iowa and other Corn Belt states (Engelken et al., 1990). Larvae feed on leaves of corn or weeds until the fourth instar, when they cause economic damage by severing corn seedlings at the base (Showers et al., 1983).

Entomopathogenic nematodes are promising biological control agents of black cutworm larvae (Capinera et al., 1988; Levine and Oloumi-Sadeghi, 1992; Morris et al., 1990). Laboratory assays indicate that *S. carpocapsae* (Weiser) is highly virulent to black cutworm (Morris et al., 1990). *Steinernema carpocapsae* has successfully controlled black cutworm under field conditions (Levine and Oloumi-Sadeghi, 1992), yet the level of efficacy is not consistent (Capinera et al., 1988).

Different fertilizers can reduce the fitness of entomopathogenic nematodes (Bednarek and Gaugler, 1997; Shapiro et al., 1996). These studies did not demonstrate if the reduced nematode fitness affects ability to prevent plant injury under field conditions. Ultimately, it is a reduction of plant injury that defines the success of a pest management strategy. Our objective was to determine the effects of selected fertilizers on *S. carpocapsae's* ability to reduce black cutworm damage in a corn ecosystem.

MATERIALS AND METHODS

Research to determine fertilizer effects on control of black cutworm by *S. carpocapsae* was conducted on the Iowa State University Research Farms in Ankeny, Iowa (1993), and in Ames, Iowa (1994). Fresh manure (less than 24 hours old) was obtained from the Iowa State University dairy held in Ankeny. Compost (''Fertilife, Compost and Manure'') was produced by Hyponex (Marysville, OH). Total Kjeldahl nitrogen was estimated to be 1.4% (dry) for both compost and fresh manure. Organic matter content (determined by acid digestion) was approximately 43% and 49% (dry) for manure and compost, respectively. *Steinernema carpocapsae* (All strain) was obtained from Biosys (Columbia, MD) and cultured in the last instar of the greater wax moth, *Galleria*

mellonella (L.), according to procedures described by Woodring and Kaya (1988).

Experiments were organized as randomized block designs with four blocks and eight treatments resulting in 32 experimental units. Experimental units were field plots, 0.4 m × 0.55 m, planted with hybrid field corn in 2 rows of 10 seeds each with 20 cm between the rows and 5 cm between seeds. Corn cv. Jacques 2103 was planted 29 July 1993, and cv. Garst 8555 was planted 6 June 1994. Fertilizer treatments were two rates of fresh cow manure, composted manure, and urea. Two controls were established: One with nematodes but no fertilizer, and one without fertilizer or nematodes. One day prior to planting, fertilizers were applied to plots and mixed to a depth of approximately 6 cm. Soil in control plots was also mixed, but no fertilizer was applied.

Total nitrogen in the two fertilizer rates was standardized to approximately 280 kg/ha and 560 kg/ha, corresponding to approximately 31 tons/ha and 62 tons/ha of fresh manure, respectively (National Research Council, 1989). These rates of manure are high but not atypical (Bednarek and Gaugler, 1997; National Research Council, 1989; Young et al., 1985).

When corn reached the first leaf stage (Ritchie et al., 1997), *S. carpocapsae* and black cutworm were added to the plots. Nematodes were applied at a rate of approximately 1.25×10^5 infective juveniles/m^2. Approximately 1,350 nematodes were applied (in the rows) about 5 cm from the spot that each seed had been planted. Nematodes, suspended in 4 ml of distilled water, were poured from polystyrene containers onto the soil surface. The containers were then rinsed with an additional 3 ml of distilled water, which was poured onto the site of nematode application. Following nematode application, 10 fourth-instar black cutworm were added to the center of each plot. To prevent escape of black cutworm larvae, the seedling beds were surrounded by 15-cm-high aluminum barriers, which were sunk to a depth of approximately 7 cm. Petroleum jelly was applied to the upper 3 cm of the barriers, and all plots were covered with fiber-glass netting to prevent bird predation.

Damage from black cutworm larvae was evaluated 10 days after nematode/black cutworm inoculation. Data from 1993 and 1994 were combined. Treatment and year effects were determined with analysis of variance on mean percentage cut plants in each plot. Differences among treatments were elucidated with Duncan's multiple-range test.

Results and Discussion

Significant treatment and year effects were detected (P = 0.0003 and 0.034, respectively). There was not, however, a significant interaction between year and treatment (P > 0.05). All nematode treatments, except those in plots with the higher rate of fresh manure, caused a significant reduction in black cutworm damage relative to plots without nematodes (Fig. 1). Nematode applications to soil amended with either rate of fresh manure resulted in more cut plants compared with nematode plots without fertilizer (Fig. 1). Black cutworm damage was not different in plots with urea and composted manure relative to nematode plots without fertilizers (Fig. 1).

A high rate of fresh manure reduced nematode efficacy. The 560-kg N/ha rate of fresh manure had a more pronounced effect than the 280-kg N/ha rate. It is likely that lower rates of fresh cow manure would not have detrimental effects on *S. carpocapsae* efficacy.

Our results are consistent with other research concerning the effects of manure on *S. carpocapsae*. In field studies, Shapiro et al. (1996) reported that the virulence of *S. carpocapsae* (against *G. mellonella*) was reduced by the presence of fresh cow manure but not by composted manure. Poultry manure has been demonstrated to reduce the survival of *S. carpocapsae* (Mullens et al., 1987), whereas bark compost increased survival of *S. carpocapsae* (Ishibashi and Kondo, 1986). Shapiro et al. (1996) concluded that the detrimental effects of fresh manure on *S. carpocapsae* might be due to processes during decomposition. Decomposition of manure may re-
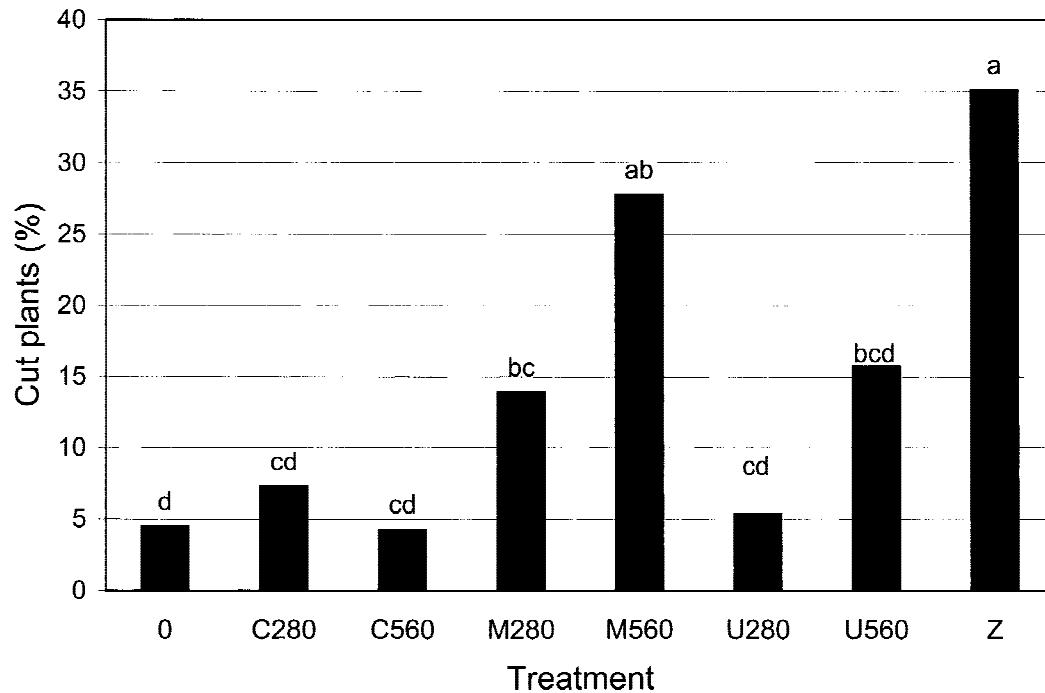
FIG. 1.   Effect of fertilizer treatments on mean percentage of plants cut by black cutworm, *Agrotis ipsilon:* 0: no fertilizer; Z: no fertilizer and no nematodes; M: manure; C: compost; U: urea. 280 and 560 correspond to nitrogen rates of 280 and 560 kg N/ha, respectively. *Steinernema carpocapsae* was applied at a rate of $1.25 \times 10^5/m^2$ in all treatments except Z.

duce oxygen availability (Simpson, 1986) and release substances that are toxic to nematodes (Kaplan and Noe, 1993).

The effects of manure on other species of entomopathogenic nematodes vary. Georgis et al. (1987) reported poultry manure to be detrimental to the biocontrol potential of *S. feltiae* (SN strain) and *Heterorhabditis bacteriophora* (NC strain). Taylor et al. (1998), however, found that *S. feltiae* (SN and UNK-36 strains), *H. bacteriophora* (Oswego strain), and *H. megidis* (HF-85 strain) persisted in fresh cattle manure and were capable of suppressing larvae of the house fly, *Musca domestica* L., in that medium. Bednarek and Gaugler (1997) reported higher endemic populations of *S. feltiae* in plots amended with manure than in untreated plots. Thus, it seems that the effects of manure on entomopathogenic nematodes depend on the manure type and the nematode species.

Bednarek and Gaugler (1997) reported that short-term exposure (10 days or less) of inorganic fertilizers was not harmful to *S.*

feltiae. Similarly, our study indicates no detrimental effect of an inorganic fertilizer (urea) on *S. carpocapsae* during a 10-day period (especially if the rate of application is 280 kg N/ha or less). In field studies, however, Bednarek and Gaugler (1997) reported that long-term exposure (>10 days) to soil amended with NPK fertilizer is detrimental to *S. feltiae.* During a 60-day field study, Shapiro et al. (1996) did not detect a reduction in *S. carpocapsae* fitness in plots amended with high rates of urea. As with manure, the effects of inorganic fertilizers on entomopathogenic nematodes depend on the specific fertilizer and the nematode species (Bednarek and Gaugler, 1997). This may explain the divergence in observations of long-term effects of inorganic fertilizers.

Other field studies have indicated significant control of the black cutworm with *S. carpocapsae* (Capinera et al., 1988; Levine and Oloumi-Sadeghi, 1992). The latter authors achieved increased control of black cutworm with a rate of $1.25 \times 10^5/m^2$ com-

pared with a rate of $2.5 \times 10^5/\mathrm{m}^2$ (11% and 25% cut plants, respectively). We confirmed that plant injury from black cutworm can be controlled with *S. carpocapsae* using the low rate of $1.25 \times 10^5/\mathrm{m}^2$.

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