Chemical Control of Selected Plant-Parasitic Nematodes in Soybeans Double-Cropped with Wheat in No-Till and Conventional Tillage Systems

D. P. SCHMITT, Associate Professor, Department of Plant Pathology, P.O. Box 7616, North Carolina State University, Raleigh 27695-7616, and L. A. NELSON, Professor, Department of Statistics, P.O. Box 8203, North Carolina State University, Raleigh 27695-8203

ABSTRACT

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Efficacy of aldicarb, ethylene dibromide (EDB), and fenamiphos for control of selected plant-parasitic nematodes, with emphasis on *Heterodera glycines*, was determined in no-till- and conventional tillage-planted soybeans. Greatest numbers of *H. glycines* eggs recovered 2 mo after planting were in conventionally tilled plots. Populations of *Tylenchorhynchus claytoni* were lowest in in-row subsoiled, no-till treatments and highest in no-till, nonsubsoiled treatments. Nematicide effects were not consistent across years as measured by population densities. Profitable yields every year were achieved only in in-row subsoiled, no-till plots treated with EDB. The nonfumigant nematicides may not give enough economic benefits to justify their use on soybeans grown after small grains in *H. glycines*-infested fields.

Additional key words: *Glycine max*

About 25–40% of the annual soybean crop in North Carolina is planted after wheat or other small-grain crops. Control of *Heterodera glycines* Ichinohe in soybean double-cropped with small grains within the same year is largely limited to the use of resistant cultivars and nematicides. Current resistant cultivars are effective in about 40% of the fields in North Carolina (D. P. Schmitt, *unpublished*). The remaining fields are infested primarily with races 2 or 5, which damage all commercial cultivars. Thus, it becomes important to determine the efficacy of nematicides for control of *H. glycines* and other nematodes on soybeans double-cropped with wheat, or other small grains, especially when the soybeans are planted with no tillage.

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The method of application in the field is an important aspect of nematicide performance. Generally, placement of aldicarb and fenamiphos in bands is more effective in controlling nematodes than in the seed furrow (10,11). Nematicide activity in relation to placement may depend on the nematode species to be controlled. For example, *Hoplolaimus columbus* Sher was controlled with dibromochloropropane (DBCP) placed in the row or to the side of the row, deep or shallow; however, consistent control of *Meloidogyne incognita* (Kofoid & White) Chitwood occurred only if DBCP was placed 13 cm from the row on both sides and 20 cm deep (7).

In no-till situations, the quantity of small-grain straw and stubble left in the field may affect delivery of nematicides. A dense layer of straw may prevent granules or liquid sprays of nonfumigant nematicides from making contact with the soil or may inhibit chemical activation. Once the problem of delivery of fumigants into the soil along with adequate sealing in no-till has been resolved, good control should be achieved. Control of *Pratylenchus* spp. with dichloropropane was equally effective in no-till and conventional tillage (5). Physical disturbances of the soil are minimized with no-till equipment. The organic matter distribution differs considerably as well as the breakdown of the residue between no-till and conventional tillage (3). These factors may alter the movement and activity of nematicides.

Tillage alone affects nematode populations but may require several years to have a measurable effect (2,13). Total nematode populations (9) and those of individual species or trophic groups such as *Helicotylenchus pseudorobustus* (Steiner) Golden (5), *M. incognita* (5), fungivores (8), and predators (8) tend to be more abundant in no-till than in tilled soils. In contrast, predacious nematodes are more abundant in conventional than in no-till systems (2). Nematodes found in greater numbers in conventional tillage than in no-till include *Pratylenchus* spp. (5), bacteriavores (8), and Tylenchinae (9). Many nematode species and trophic groups are not affected by tillage (1,2,9,13).

The presence or absence of a small-grain crop prior to tillage treatment may have an influence on the nematode community. Numbers of *Heterodera glycines* second-stage juveniles were greatest in July in the conventional tillage treatments not preceded by wheat; by October, these differences were no longer evident (2).

The objective of this research was to determine the efficacy of three nematicides for the control of nematodes under conventional tillage- and no-till-planted, double-cropped soybeans after wheat harvest.

MATERIAL AND METHODS

Three experiments, one location per year, were conducted from 1981 to 1983

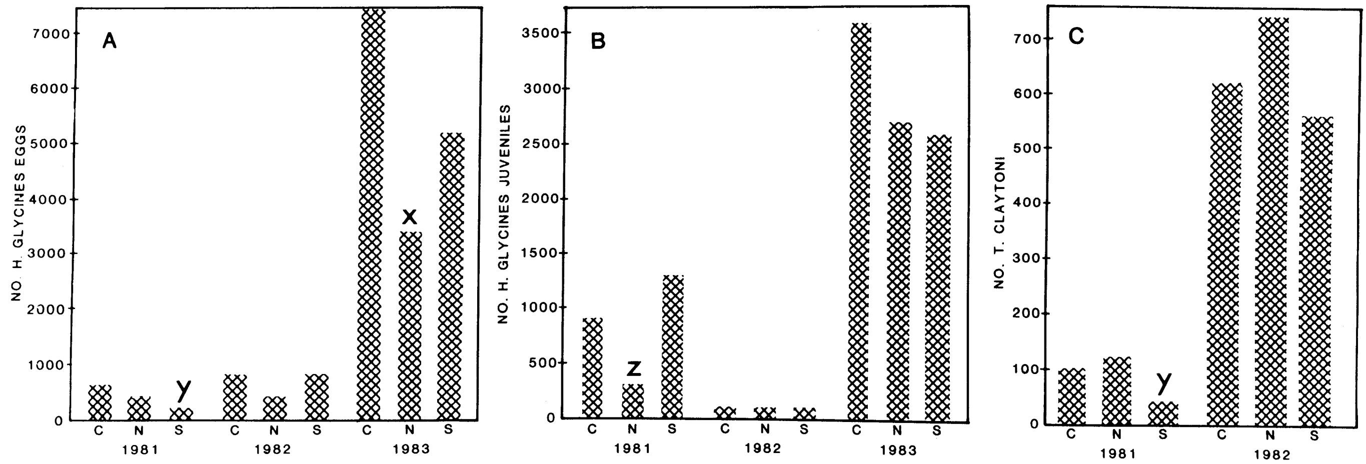

Fig. 1. Main effects of tillage treatments on nematode population densities about 2 mo after planting soybeans double-cropped with wheat near Weeksville, NC: **(A)** *Heterodera glycines* eggs, **(B)** *H. glycines* juveniles, and **(C)** *Tylenchorhynchus claytoni* in numbers per 500 cm^3 of soil. x = Significantly different (P = 0.05) from conventional tillage treatments within year, y = significantly different (P = 0.05) from conventional tillage and no-till treatments within year, and z = significantly different (P = 0.05) from conventional tillage and in-row subsoil tillage treatments within year. C = conventional tillage, N = no tillage, and S = in-row subsoiled, no tillage. The probability of a greater F for tillage was determined with analysis of variance of data for a split-plot (1981 and 1982) or randomized complete block design with treatments factorially arranged (1983). Means were separated with a Waller-Duncan LSD (k-ratio = 100).

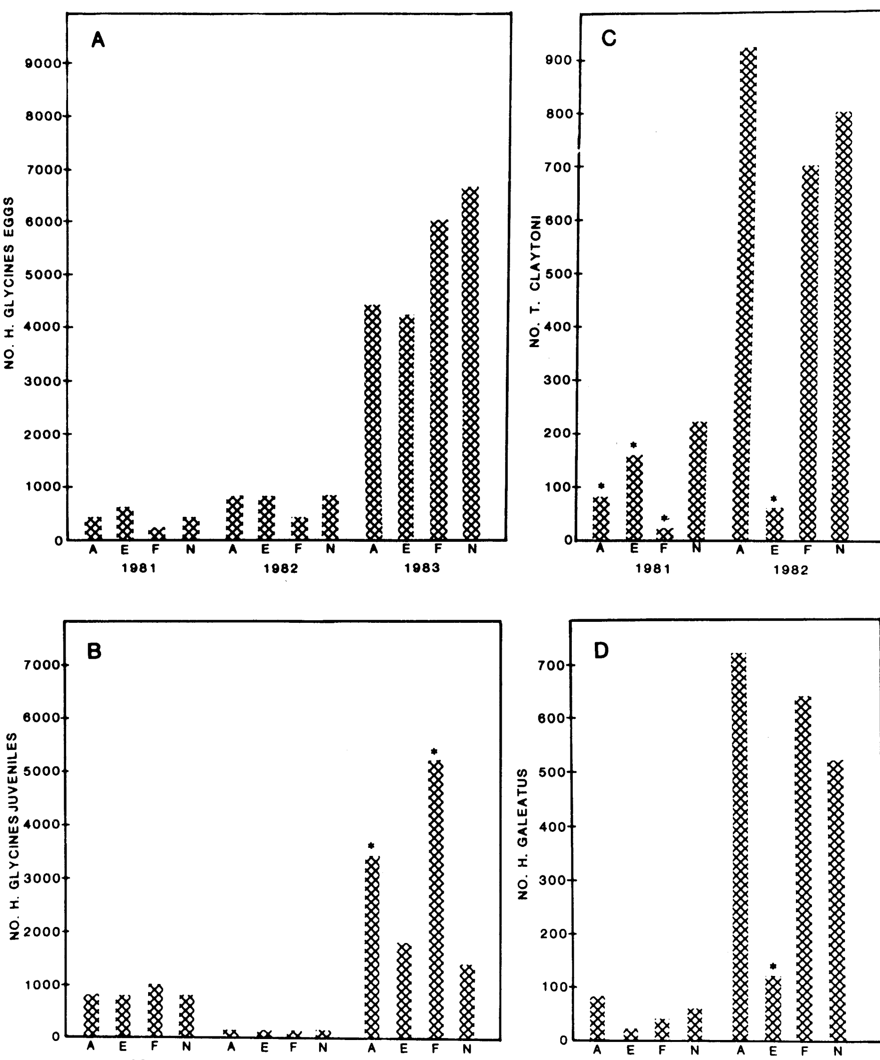

Fig. 2. Nematicide main effects on numbers of nematodes about 2 mo after planting soybeans double-cropped with wheat near Weeksville, NC: **(A)** *Heterodera glycines* eggs, **(B)** *H. glycines* juveniles, **(C)** *Tylenchorhynchus claytoni*, and **(D)** *Hoplolaimus galeatus* expressed in numbers per 500 cm^3 of soil. * = Different (P = 0.01) from untreated control within year. A = aldicarb, E = EDB, F = fenamiphos, and N = untreated control. The probability of a greater F for nematodes was determined with analysis of variance of data for a split-plot (1981 and 1982) or randomized complete block design with treatments factorially arranged (1983). Means were separated with a Waller-Duncan LSD (k-ratio = 100).

near Weeksville, NC, in fields where *Heterodera glycines* was the dominant nematode. At each location, one-third of the plots were tilled after wheat was harvested and two-thirds were left undisturbed (no-till). Half of the no-till plots were planted with conventional no-till equipment and the other half were in-row subsoiled and planted with a commercial subsoiler-planter designed for no-till. The subsoiler was designed to operate to a 35-cm depth. All plots were planted with Coker 156 soybean (*Glycine max* (L.) Merr.) (susceptible to *H. glycines*) and treated simultaneously with either aldicarb, fenamiphos, or ethylene dibromide (EDB), except in 1981, when EDB was applied in a separate operation just before planting in the nonsubsoiled plots. EDB (1.28 ml/m of row) was injected 20 cm deep in the nonsubsoiled plots and 35 cm deep in the subsoiled plots. Fenamiphos (0.2 g a.i./m of row) and aldicarb (0.15 g a.i./m of row) were applied in the seed furrow.

Soil samples for nematode assay were collected from the center two rows of each plot before treatment and again about 2 mo after planting. Ten to 12 2.5-cm-diameter cores were taken 15–20 cm deep from the row and composited. Nematodes were extracted from 500 cm^3 of soil by a combination of elutriation (4) and centrifugation (6).

Location 1 (1981). The experimental design was a split plot with randomized complete block arrangement of the whole plots (total of four blocks). Plots were 4 m wide by 30.5 m long. Tillage treatments were whole plots and nematicides were subplots. The surface soil (0–20 cm) texture was sandy loam (57% sand, 39% silt, 4% clay, organic matter $< 1\%$). Soybeans were planted 22 June 1981, sampled 22 June and 18 August, and harvested 19 November. The herbicides alachlor (2.2 kg a.i./ha) and glyphosate

(2.2 kg a.i./ha) were applied immediately after planting.

Location 2 (1982). The experimental design was as in site 1. The surface soil (0–20 cm) texture was sandy loam (53% sand, 40% silt, 7% clay, organic matter <1%). Plots were 4 m wide by 15.3 m long. Soybeans were planted 22 June 1982 and harvested 10 November. Soil samples for nematode assay were collected on 21 June and 30 August. The herbicides metolachlor (2.2 kg a.i./ha) and glyphosate (2.2 kg a.i./ha) were applied immediately after planting.

Location 3 (1983). A randomized complete block design experiment with treatments arranged according to a 4 × 3 factorial involving three tillage and four nematicide treatments, with four replicates, was conducted in a sandy loam soil (texture not determined but similar to locations 1 and 2). Plots were 3.9 m wide by 12.2 m long. Soybeans were planted 27 June and harvested 1 December. Soil samples for nematode assay were collected 27 June and 16 August. Weeds were controlled with a tank mixture of glyphosate (3.4 kg a.i./ha), alachlor (2.2 kg a.i./ha), and linuron (0.57 kg a.i./ha).

Statistical methods. The data from all of the experiments were analyzed with an appropriate analysis of variance. In cases where an interaction between tillage and nematicide was not present, main effect means were compared with the Waller-Duncan *k*-ratio *t* test. Where interactions were present, these comparisons were made on simple effect means. A combined analysis of variance for all sites was not performed because of differences in years, locations, and experimental design.

RESULTS

The most consistent treatment effects were on number of eggs of *Heterodera glycines*. The highest numbers of eggs 2 mo after planting occurred each year under conventional tillage but were only significant ($P = 0.05$) from subsoiled, no-till plots in 1981 and no-till plots in 1983 (Fig. 1). Juvenile populations did not respond consistently to tillage (Fig. 1). Numbers of *Tylenchorhynchus claytoni* Steiner were lowest ($P = 0.05$) in subsoiled, no-till plots and highest in no-till plots (Fig. 1).

Control of *H. glycines* with nematicides was not consistent across years. Sufficient rainfall to thoroughly wet the soil (amount not measured) occurred soon after planting and treatment in 1981 and 1982. In those years, the populations of eggs were lowest in plots treated with fenamiphos, although the differences were not significant (Fig. 2A). In 1983, a dry year, fewer eggs ($P = 0.27$) were extracted from plots treated with aldicarb and EDB than from plots treated with fenamiphos or not treated (Fig. 2A). Juvenile population densities increased in 1983 in aldicarb- and fenamiphos-treated soil (Fig. 2B). *T. claytoni* was controlled ($P = 0.01$) by all nematicides in 1981, but only EDB was effective in 1982 (Fig. 2C). *Hoplolaimus galeatus* (Cobb) Filipjev & Shuurmans-Stekhoven also was controlled ($P = 0.01$) by EDB in 1982 (Fig. 2D).

There was a tillage × nematicide interaction ($P = 0.01$) for yield in 1981 but only a tillage effect ($P = 0.02$) in 1982 and tillage ($P = 0.04$) and nematicide ($P = 0.04$) main effects in 1983 (Table 1). In 1981, nematicides were not effective in changing yield under conventional tillage; however, yields were increased with the nonfumigants with no-till and with all nematicides in subsoiled, no-till plots. Yields were highest in subsoiled, no-till treatments in all three years and lowest in conventional tillage treatments in two of three years. Nematicides generally gave slight but nonsignificant yield increases in 1982–1983. Only EDB in the subsoiled, no-till treatment gave a net profit in all three years of this study.

DISCUSSION

Adequate and consistent nematode control to produce profitable yields was not achieved with nematicides in soybeans double-cropped with wheat, with the exception of EDB applied in the in-row subsoiled, no-till treatment. In-furrow placement of nematicides on soybeans grown for a full season in

Table 1. Yield (kg/ha) and net change[m] in crop value from nematicide treatment of Coker 156 soybeans double-cropped with wheat in sandy loam soils near Weeksville, NC, under different tillage regimes

Nematicide[n]	Tillage[n]: Conventional	No-till	Subsoiled, not tilled	Mean
1981				
None	865 ax	1,226 by	1,088 ax	1,060
EDB	845 ax(−$31.40)	828 ax(−$124.56)	1,575 by($70.14)	1,083
Fenamiphos	783 ax(−$99.99)	1,594 cy(−$0.99)	1,584 by($27.17)	1,320
Aldicarb	1,028 ax(−$25.74)	1,704 cy($43.56)	1,764 by($87.12)	1,499
Mean	880	1,338	1,503	
ANOVA: tillage × nematicide ($P = 0.01$)				
1982				
None	2,345	2,265	2,609	2,406 a
EDB	2,339 (−$38.32)	2,569 ($29.88)	2,941 ($36.04)	2,617 a
Fenamiphos	2,239 (−$105.27	2,600 (−$8.25)	2,559 (−$92.95)	2,466 a
Aldicarb	2,395 (−$50.60)	2,320 (−$49.50)	2,646 (−$53.46)	2,454 a
Mean	2,330 z	2,439 y	2,689 x	
ANOVA: tillage ($P = 0.02$), nematicide ($P = 0.09$); tillage × nematicide ($P = 0.14$)				
1983				
None	2,098	2,050	2,111	2,085 ab
EDB	2,313 ($10.34)	1,969 (−$54.82)	2,596 ($69.70)	2,293 ab
Fenamiphos	1,855 (−$135.41)	1,827 (−$131.01)	2,307 (−$38.83)	1,995 b
Aldicarb	2,542 ($36.08)	2,205 (−$27.50)	2,327 (−$14.08)	2,359 a
Mean	2,203 xy	2,012 y	2,334 x	
ANOVA: tillage ($P = 0.04$), nematicide ($P = 0.04$); tillage × nematicide ($P = 0.37$)				

[m] Net change was computed as the change in soybean value at $0.22/kg minus cost of aldicarb = $61.60/ha, fenamiphos = $81.95/ha, and EDB = $37.00/ha compared with the untreated control.

[n] For 1981, tillage means for the same nematicide treatment (across rows) followed by the same letter, x or y, are not significantly different. Nematicide means for the same tillage treatment (down columns) followed by the same letter, a, b, or c, are not significantly different according to the Waller-Duncan LSD (*k*-ratio = 100). For 1982 and 1983, tillage main effect means followed by the same letter, x, y, or z, are not significantly different according to the Waller-Duncan LSD (*k*-ratio = 100). For 1983, nematicide main effect means followed by the same letter, a or b, are not significantly different according to the Waller-Duncan LSD (*k*-ratio = 100). Probabilities given for each ANOVA signify the probability of a greater *F* associated with the *F* calculated for each source of variation.

conventionally tilled soil has given nematode control and yield increases (7,11).

The performance of aldicarb and fenamiphos was very inconsistent, presumably because of soil moisture. For example, 1982 was a relatively wet year and 1983 was a dry year. If aldicarb had remained in the root zone in 1983, it could have had a suppressive effect on egg population development and increased seed yield. Aldicarb's poor performance in 1982 could be partially caused by leaching of this nematicide.

Deep placement of EDB is necessary in the sandy loam soil textures of North Carolina to give a significant yield response. The concentration × time factor (12) is probably achieved by the deep placement resulting in the chemical being held long enough in the zone where the nematodes are active to kill them. Placement is not important for some nematodes such as *Hoplolaimus columbus* (7), and deep placement may give poor control of *M. incognita* (7).

The effective use of nematicides for nematode management in no-till systems will require information on soil characteristics affecting the movement and behavior of the pesticides. Factors such as nematicide movement in soil may be altered by tillage practices and soil moisture. However, use of nematicides on soybeans planted with no-till or conventional tillage methods after wheat harvest may not be economically feasible.

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