Interaction of Fensulfothion and Phorate with Preemergence Herbicides on Soybean Parasitic Nematodes[1]

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Abstract: The herbicides alachlor, linuron, vernolate, and metribuzin were applied to plots treated with the nematicide fensulfothion or the insecticide phorate and planted to soybean in two locations in North Carolina. In 1976 treatment with fensulfothion + alachlor or vernolate, phorate + alachlor or metribuzin resulted in greater nematode population densities than no treatment, or treatment with fensulfothion alone, or phorate alone. In 1977 fensulfothion and phorate alone and in combination with the preemergence herbicides effectively controlled *Tylenchorhynchus claytoni*. Late season population resurgence of *Heterodera glycines* occurred in fensulfothion + alachlor treated plots. Correlation coefficients for *H. glycines* vs. yield were -0.48 ($P = 0.05$) and -0.46 ($P = 0.05$) for 30 and 68 d after planting, respectively. *Key words:* pesticide interaction, insecticide, nematicide, control, resurgence, *Helicotylenchus dihystera, Heterodera glycines, Tylenchorhynchus claytoni.*

Growers and commercial applicators often apply pesticides in combination. Research on the interaction of pesticides has been directed primarily at the effects on the crop plant as summarized by Putnam and Penner (13). Some combinations of herbicides, or herbicides and insecticides, were more active than one component by itself, whereas other combinations rendered one of the chemicals less active (13). Relatively little has been published on the effects of pesticide combinations on nematode control. Some researchers (1,2,3,12) have found that a nematicide mixed or used in combination with fungicides and/or herbicides resulted in significant differences in nematode control compared to the nematicide alone.

More research has been done on the effect of herbicides and nematicides on nontarget organisms. The herbicides EPTC, fluometeron and diuron inhibited the fungi *Sclerotium rolfsii* Sacc. and *Sclerotinia trifoliorum* Eriks. (5). Herbicide treated plants were more resistant to *Rhizoctonia solani* Keuhn, *Fusarium*, or *Verticillium dahliae* Kleb. than untreated plants (6). The nematicide ethoprop inhibited growth of *S. rolfsii* and *R. solani* in culture, and it consistently suppressed damage by *S. rolfsii* on peanuts when it was applied at blooming (14).

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The objective of this research was to determine the effects on nematode populations of certain preemergence herbicides applied after treatment with the insecticide phorate or the nematicide fensulfothion.

MATERIALS AND METHODS

Tests were conducted in fields at the Upper Coastal Plains Research Station near Rocky Mount, North Carolina, in 1976 (Experiment 1). The soil at this station was a Norfolk sandy loam. In 1977 (Experiment 2) the test field was at the Central Crops Research Station near Clayton, North Carolina, where the soil was a Varina sandy loam. Treatments applied at the two stations are shown in Table 1. The dominant plant-parasitic nematode at the field at the Upper Coastal Plains Research Station was *Helicotylenchus dihystera* (Cobb) Sher. *Heterodera glycines* (race 1) Ichinohe and *Tylenchorhynchus claytoni* Steiner were the dominant plant-parasitic species at the Central Crops Research Station.

Fensulfothion was applied in a 30-cm band and incorporated with a tractor-drawn rolling tine at planting in 1976 and with a rototiller in 1977. Phorate was applied in the planting furrow both years. Soybeans, *Glycine max* (L.) Merr. 'Ransom' were planted in all plots. Fensulfothion and phorate were applied and soybeans planted on 16 June 1976 and 15 June 1977. The herbicides alachlor, linuron, metribuzin, or vernolate were sprayed over the entire soil surface within plots by 2 d after planting.

Plots were four rows wide and 12 m long (1976) or 9 m long (1977). Treatments were arranged in a randomized complete block

Table 1. Treatments used to determine the effects of pesticide combinations on soil nematodes associated with soybean.

Treatment	Class	Chemical rates (kg ai/ha) Upper Coastal Plains Research Station—1976	Central Crops Research Station—1977
Untreated control			
Fensulfothion	Insecticide-nematicide	2.24	2.24
Phorate	Insecticide	1.12	1.12
Alachlor	Herbicide	4.48	4.48
Linuron	Herbicide	1.12	1.12
Metribuzin	Herbicide	0.56	0.56
Vernolate	Herbicide	4.48	
Fensulfothion + alachlor		2.24 + 4.48	2.24 + 4.48
Fensulfothion + linuron		2.24 + 1.12	2.24 + 1.12
Fensulfothion + metribuzin		2.24 + 0.56	2.24 + 0.56
Fensulfothion + vernolate		2.24 + 4.48	
Phorate + alachlor		1.12 + 4.48	1.12 + 4.48
Phorate + linuron		1.12 + 1.12	1.12 + 1.12
Phorate + metribuzin		1.12 + 0.56	1.12 + 0.56
Phorate + vernolate		1.12 + 4.48	

design with four replications of each treatment. Data were collected from the center two rows.

A composite of 10–12 soil cores 2.5-cm d taken to a depth of 15–20 cm was collected from the center two rows of each plot. In 1976 soil samples for nematode assay were taken from each plot before treatment and at 60 and 180 d after treatment. In 1977 samples were taken at monthly intervals.

Different extraction techniques were used each year. In 1976 a 100 cm^3 subsample was taken from each composite sample and processed by a modification of a centrifugal-flotation technique (8). In 1977, 500 cm^3 of soil were processed with a semi-automatic elutriator (4) and centrifugal-flotation (8).

Treatment means were compared with a least significant difference (LSD) if the F value in the analysis of variance was significant.

RESULTS

Experiment 1: Helicotylenchus dihystera populations were unaffected ($P = 0.05$) by most pesticides alone and in combination. At 60 d, alachlor + phorate or fensulfothion increased their numbers above the untreated control, phorate alone, and fensulfothion alone (Table 2). By 180 d after planting, there were more ($P = 0.05$) *H. dihystera* in fensulfothion + alachlor and fensulfothion + vernolate-treated plots than in the untreated control or the fensulfothion treatment. This response also occurred in the vernolate treatment compared to the untreated control.

Table 2. Effect of pesticides and pesticide combinations on the population density of *Helicotylenchus dihystera* at Rocky Mount, North Carolina, 1976.

Treatment	No. of *H. dihystera*/100 cm^3 soil 60 d	180 d
Untreated control	65	65
Fensulfothion	55	138
Fensulfothion + alachlor	330	588
Fensulfothion + metribuzin	52	55
Fensulfothion + vernolate	72	345
Phorate	68	150
Phorate + alachlor	242	299
Phorate + metribuzin	115	188
Alachlor	72	200
Metribuzin	105	140
Vernolate	170	308
LSD (0.05)	178	203

Bacterial feeding nematode numbers were enhanced ($P = 0.05$) by vernolate, alachlor, linuron, and metribuzin over the untreated control. Metribuzin or alachlor + phorate resulted in more ($P = 0.05$) of these nematodes than phorate alone. Phorate and fensulfothion + metribuzin reduced ($P = 0.05$) their populations below the untreated control.

Experiment 2: Reduction ($P = 0.05$) of the total plant-parasitic nematode population was achieved only with fensulfothion + linuron or metribuzin. There were 465 plant-parasitic nematodes/500 cm^3 soil in the untreated control and 103 and 130 in the respective combinations at 68 d.

Fensulfothion and phorate alone and in combination with either alachlor, linuron, or metribuzin provided control ($P = 0.05$) of *Tylenchorhynchus claytoni* (Table 3). The herbicides alone had no apparent effect on this nematode.

Population density differences of *Heterodera glycines* juveniles were not significantly different at $P = 0.05$, but the probabilities were between 0.05 and 0.10 (Table 3).

At 97 d, the population density of *H. glycines* was 11.8-fold greater after fensulfothion + alachlor treatment than with no treatment. They were also 3.1-fold greater with fensulfothion + alachlor than with fensulfothion alone.

Fresh shoot weights from pesticide-treated plots did not differ ($P = 0.05$) from the untreated control (Table 4). Likewise, shoot weights from phorate or fensulfothion treated plots did not differ ($P = 0.05$) from these pesticides + herbicides. Metribuzin plus either organophosphate reduced ($P = 0.05$) shoot weights below the highest yielding plots. The correlation coefficients for *H. glycines* vs. shoot weight were –0.48 ($P = 0.05$) and –0.46 ($P = 0.05$) for 30 and 68 d after planting, respectively.

Table 4. Shoot weight of Ransom soybean treated with pesticides at the Central Crops Research Station, Clayton, North Carolina, 1977.

Treatment	Fresh shoot wt (g/3 m of row)
Untreated control	1,393
Fensulfothion	1,785
Fensulfothion + metribuzin	1,168
Fensulfothion + alachlor	2,285
Fensulfothion + linuron	1,588
Phorate	1,105
Phorate + alachlor	1,495
Phorate + metribuzin	283
Phorate + linuron	2,135
Alachlor	1,343
Linuron	1,320
Metribuzin	1,070
LSD (0.05)	1,168

DISCUSSION

Phorate and fensulfothion are poor nematicides and caused little reduction in nematode populations. In some cases nematode control with fensulfothion was improved in combination with a herbicide. For example, populations of *H. glycines* + *T. claytoni* + small numbers of other plant-parasitic nematodes were reduced signif-

Table 3. Effects of pesticides alone and in combination on the population density of *Heterodera glycines* and *Tylenchorhynchus claytoni* at Clayton, North Carolina, 1977.

Treatment	No. nematodes/500 cm^3 soil					
	Heterodera glycines juveniles			*Tylenchorhynchus claytoni*		
	30 d	68 d	97 d	30 d	68 d	97 d
Untreated control	165	125	58	78	250	365
Fensulfothion	33	188	223	10	58	50
Fensulfothion + alachlor	55	125	683	28	30	193
Fensulfothion + linuron	40	73	285	3	10	25
Fensulfothion + metribuzin	85	78	152	0	23	45
Phorate	170	367	420	5	0	10
Phorate + alachlor	103	158	235	0	43	15
Phorate + linuron	98	105	258	13	113	80
Phorate + metribuzin	75	270	228	25	75	76
Alachlor	113	25	293	63	223	173
Linuron	10	175	450	75	340	403
Metribuzin	10	123	258	83	435	275
LSD (0.05)	NS	NS	NS	53	212	250

icantly at Clayton only by fensulfothion + linuron or metribuzin.

Pesticide combinations more commonly caused increases in nematode populations, particularly with fensulfothion + alachlor. Phorate + alachlor and alachlor alone were also associated with population increases.

The effect of alachlor on the nematodes and/or on the activity of fensulfothion or phorate may be complex. The herbicide may be affecting organisms other than nematodes, particularly bacteria, since populations of bacteria-feeding nematodes increased with their use. Alachlor could stimulate hatching of nematode eggs. Alteration of plant metabolism by various pesticides or pesticide combinations could also affect nematode feeding and/or reproduction.

Behavior of some of these pesticides has been reported. Meyers (11) found that organic phosphates and organic carbamates affected nematode reproduction rather than viability. Hough and Thomason (7) found that concentrations of aldicarb (0.01 mg/ml in sand columns) disrupted the male sensory system of *Heterodera schachtii* Schmidt so that it could not find females.

The role of herbicides on nematodes, particularly in combination with nematicides is poorly understood. Johnson et al. (9) demonstrated that herbicides were not nematicidal, whereas King et al. (10) found *Meloidogyne arenaria* (Neal) Chitwood root-gall density was increased over that in the control at lower rates and reduced at higher rates of the herbicides EPTC and vernolate. This response varied between peanut and tomato. The herbicides used in some of our treatments were stimulatory, yet appeared to control nematodes in other treatments. We had some stimulation in population size with vernolate alone as well as in combination wth fensulfothion. King et al. (10) suggested that the herbicides could alter the host-parasite relationship. Chemical reactions in the soil between herbicides and nematicides that alter the activity of a nematicide or insecticide have not been shown but could possibly occur.

Nematode population increases could also be a function, to some extent, of the root biomass. When roots are protected early the root biomass will generally be greater than in unprotected roots. Subsequently, after a nematicide has degraded, nematodes have a greater food base that can sustain a larger population.

The significantly lower fresh shoot weight of plants from the metribuzin + phorate or fensulfothion treatments is due primarily to phytotoxicity resulting from the interaction of the organic phosphate pesticides with metribuzin.

Extensive studies will be required to adequately evaluate the mechanisms involved in the interactions between preemergence herbicides and insecticide-nematicides and to identify compatible components in an integrated pest management system for soybeans. Although a complete explanation cannot be derived from this experiment, our studies have demonstrated the subtle changes in nematode populations which occur when herbicides—particularly alachlor, but to some extent, metribuzin and vernolate—were used in combination with an insecticide and a nematicide. In actual practice gradual or subtle changes in population densities of nematodes could go undetected unless large reductions in soybean yields are observed.

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