Supplement to Journal of Nematology 21, No. 4S:635–639. 1989.

Effects of Fertilizer and Pesticides on Soybean Growing in *Heterodera glycines*-infested Soil[1]

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Abstract: A nematicide, dibromochloropropane; the fungicides benomyl and maneb; an insecticide, oxydisulfoton; the herbicides trifluralin, linuron, and dinoseb; and fertilizers were applied to *Heterodera glycines*-infested soil. A resistant soybean cultivar alone produced the highest yield in one test, and its yield was not affected by application of pesticides or fertilizer. In two tests the cultivar that was supposed to be resistant was not. Application of nematicide alone resulted in higher yields of the susceptible cultivar, compared with the untreated check, in only one of three tests. Various combinations of pesticides also resulted in higher yields, and in all cases the nematicide was included. Pesticides and fertilizer must be used with discretion on soybean.

Key words: fertilizer, fungicide, *Glycine max,* herbicide, *Heterodera glycines,* insecticide, nematicide, soybean, soybean cyst nematode.

A number of pesticides and fertilizers are applied to soil on which soybean is grown. These pesticides may be specific for a target organism, but their effects on other organisms may not be known. For example, some herbicides may affect soybean cyst nematodes (SCN), *Heterodera glycines* Ichinohe, whereas others are not known to affect this nematode (1–4). When *H. glycines*-infested soil was treated with alachlor alone or in combination with aldicarb, fenamiphos, or ethoprop, the density of *H. glycines* eggs and second-stage juveniles was higher in August and November in treated plots than in the untreated control (4). Yields were negatively correlated with *H. glycines* density (4).

Heterodera glycines juvenile and egg densities at midseason and harvest were higher following a preplant application of alachlor when fenamiphos or ethoprop was applied than in the untreated control (1). Seed yields were greater in plots treated with fenamiphos alone or fenamiphos plus alachlor than in plots treated with ethoprop alone or ethoprop plus alachlor (1). Fensulfothion plus alachlor or vernolate and phorate plus alachlor or metribuzin treatments resulted in higher nematode densities than did no treatment or a treatment with fensulfothion or phorate alone (3). Vernolate, trifluralin, or metribuzin at recommended rates increased *H. glycines* juvenile densities in soil by 43–82% at 14 days after treatment and white females by 133–251% at 5 weeks after treatment, compared with the untreated control (2).

Our objectives were to determine the effects of pesticides and fertilizer, alone or in different combinations, on soybean yield on soils infested with SCN.

Materials and Methods

Three experiments were conducted between 1973 and 1977 on a silt loam soil infested with 500 second-stage juveniles (J2) of *H. glycines* per 500 cm^3 of soil at the Cotton Branch Experiment Station, Marianna, Arkansas. Plots, four rows 0.9 m apart and 15.3 m long, were arranged in a randomized complete block design. Treatments were replicated four times. They were applied with custom-made applicators (nematicide, insecticide, fungicide, and fertilizer) or with regular tillage equipment (herbicide).

Soybean (*Glycine max* (L.) Merr. cv. Hood) was the *H. glycines*-susceptible cultivar in 1973, and Dare was the susceptible cultivar in 1975 and 1977. The resistant cultivar was Pickett the first 2 years and Forrest the third year. Soybean was seeded at a rate of 50.4 kg/ha. Dibromochloropropane (DBCP) (95 ml/100 m of row) was injected 20 cm deep at 20 psi with a single chisel, and the opening was closed with a press

Received for publication 13 April 1988.
[1] Published with the approval of the Director of the Arkansas Agricultural Experiment Station. Supported by a grant from the Arkansas Soybean Promotion Board.
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TABLE 1. Soybean yields and soybean cyst nematode population levels from combination pesticide and fertilizer test, Cotton Branch Station, Marianna, Arkansas, 1973 and 1975.

	Yield (hl/ha)†				SCN J2/500 cm^3 soil‡			
	1973		1975		1973		1975	
Treatment	Hood	Pickett	Dare	Pickett	Hood	Pick-ett	Dare	Pick-ett
Control	8 jk	40 ab	20 defgh	7 kl	861	2,451	1,479	798
DBCP	23 cdefghi	46 a	18 efghi	13 hijkl	942	1,440	477	283
Benomyl and maneb	6 k	40 ab	15 fghijk	8 kl	1,830	2,335	4,380	2,100
Trifluralin, linuron, and dinoseb	10 hijk	35 abc	16 fghij	9 jkl	368	915	3,912	1,846
Oxydisulfoton	6 k	41 ab	14 ghijk	14 ghijkl	504	1,459	5,160	975
Fertilizer	10 hijk	42 ab	15 fghijk	8 kl	1,560	2,232	3,246	1,880
DBCP:								
+ benomyl and maneb	17 fghijk	45 a	24 abcde	13 hijkl	1,799	2,200	483	387
+ trifluralin, linuron, and dinoseb	11 ghijk	32 abcde	20 defgh	10 ijkl	1,254	2,857		439
+ oxydisulfoton	14 ghijk	33 abcd	32 a	13 hijkl	1,635	669	975	966
+ fertilizer	19 efghijk	42 ab	29 abc	22 cdefg	1,643	678	513	439
Benomyl and maneb:								
+ trifluralin, linuron, and dinoseb	13 ghijk		18 efghi		927		609	
+ oxydisulfoton	9 ijk		12 hijkl		1,161		2,151	
+ fertilzer	7 jk		13 hijkl		1,410		1,464	
Trifluralin, linuron, and dinoseb:								
+ oxydisulfoton	10 hijk		23 bcde		1,206		2,148	
+ fertilizer	11 hijk		20 defgh		755		1,082	
Trifluralin, linuron, and dinoseb + fertilizer	17 fghijk		16 fghij		1,068		3,678	
DBCP + benomyl and maneb:								
+ trifluralin, linuron, and dinoseb	12 ghijk	40 ab	29 abc	14 ghijkl	1,260	2,116	1,056	162
+ oxydisulfoton	19 efghijk		17 efghi		1,521		591	
+ fertilizer	18 fghijk		26 abcd		1,833		864	
DBCP + trifluralin, linuron, and dinoseb								
+ oxydisulfoton	10 hijk		14 ghijk		402		1,350	
+ fertilizer	6 k		13 hijkl		1,189		1,294	
DBCP + oxydisulfoton + fertilizer	24 cdefgh		13 hijkl		2,038		615	
Benomyl and maneb + trifluralin, linuron, and dinoseb:								
+ oxydisulfoton	7 jk		13 hijkl		507		1,356	
+ fertilizer	9 ijk		7 kl		492		4,485	
Benomyl and maneb + oxydisulfoton + fertilizer	10 hijk		22 cdefg		2,416		3,693	
Trifluralin, linuron and dinoseb + oxydisulfoton + fertilizer	7 jk		26 abcd		489		1,464	
DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb:								
+ oxydisulfoton	27 bcdef		28 abc		549		821	
+ fertilizer	6 k		30 ab		1,280		300	
DBCP + benomyl and maneb + oxydisulfoton + fertilizer	21 cdefghi		30 ab		3,654		492	

TABLE 1. Continued.

Treatment	Yield (hl/ha)† 1973 Hood	1973 Pickett	1975 Dare	1975 Pickett	SCN J2/500 cm³ soil‡ 1973 Hood	1973 Pickett	1975 Dare	1975 Pickett
DBCP + trifluralin, linuron, and dinoseb + oxydisulfoton + fertilizer	14 ghijk		14 ghijk		635		1,288	
Benomyl and maneb + trifluralin, linuron, and dinoseb + oxydisulfoton + fertilizer	7 jk		15 fghijk		522		1,821	
DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb + oxydisulfoton + fertilizer	10 hijk	42 ab	15 fghijk	14 ghijkl	817	1,434	540	360

Plots were four rows 0.9 m apart and 15.3 m long; treatments were replicated four times. Yields followed by the same letter are not significantly (P = 0.05) different according to Duncan's multiple-range test.
† 1 hl/ha = 1.15 bu/A.
‡ Soil samples for nematode analyses were taken 6 weeks after planting.

wheel. Trifluralin (1.2 liters/ha) was applied preplant incorporated, linuron (1.1 kg/ha) was applied postplant, and dinoseb (1.3 kg/ha) was applied as a postdirected spray. Oxydisulfoton (37 g a.i./100 m of row) was applied with a Gandy applicator (Gandy Company, Owatonna, MN) in an 18-cm band at plant and incorporated 5–8 cm deep with a rototiller. Benomyl (0.6 kg a.i./ha) and maneb (1.7 kg a.i./ha) were sprayed in 190 liters water/ha as a tank mix at the R2 stage (5) and 2 weeks later. The plots were fertilized with 224 kg/ha 6-24-24 (N-P_2O_5-K_2O) applied under the row at planting and 224 kg/ha 0-0-50 applied at about R4.

Tests in 1973 and 1975 included all treatment combinations on the susceptible cultivar and nematicide—herbicides, insecticide, fungicides, and fertilizer each alone; nematicide plus herbicides or insecticide or fungicides or fertilizer; nematicide plus herbicides plus fungicides; and all pesticides together on the resistant cultivar. In 1977 the herbicides were applied uniformly over the entire area, no fertilizer was applied, and treatments on the susceptible and resistant cultivars were identical.

All plots were cultivated two or three times to control weeds. Irrigation was available only during 1977 and rainfall was low in 1973. Temperatures were normal for the area all 3 years.

Soil samples for J2 nematode assays consisted of 10 cores (2.0 cm × 20 cm deep) taken with a soil probe 6 weeks after planting. The samples were mixed thoroughly, nematodes were extraced from a 250-cm³ aliquot by the sieving and Baermann funnel method, and J2 were counted. The two middle rows of each plot were harvested with a combine, and seed weights were recorded. Data were subjected to analysis of variance, and treatment means were compared by Duncan's multiple-range test. Correlation coefficients also were calculated.

RESULTS

Pickett with no treatment yielded higher (P = 0.05) than Hood with any treatment (Table 1). Hood treated with DBCP alone had higher yields (P = 0.05) than the untreated control or plots treated with fungicides, insecticides, or fertilizer alone in 1973 (Table 1). In 1973 treatments that included DBCP tended to yield more than

TABLE 2. Soybean yields and population densities of second-stage juveniles of soybean cyst nematode as affected by pesticides, Cotton Branch Station, Marianna, Arkansas, 1977.

Treatment	Yield (hl/ha)†		SCN J2/500 cm³ soil‡	
	Dare	Forrest	Dare	Forrest
Untreated	32	32	36	41
DBCP	36	41	7	23
Oxydisulfoton	36	40	9	23
Benomyl	36	38	39	28
DBCP + oxydisulfoton	35	41	23	9
DBCP + benomyl	41	49	28	13
Oxydisulfoton + benomyl	37	41	21	20
DBCP + oxydisulfoton + benomyl	43	47	26	8

Plots were four rows 0.9 cm apart and 15.3 m long; treatments were replicated four times.
† 1 hl/ha = 1.15 bu/A.
‡ Soil samples for nematode analyses were taken 6 weeks after planting.

those without, but only DBCP + oxydisulfoton + fertilizer; DBCP + benomyl and maneb + oxydisulfoton + fertilizer; and DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb + oxydisulfoton had higher yields ($P = 0.05$) than the untreated susceptible cultivar. When all plots treated with nematicide, alone or in combination, were compared with those not receiving nematicide, the yields from treated plots were higher ($P = 0.05$). There were no differences in numbers of *H. glycines* J2/500 cm³ soil even though several treatments had numerically larger numbers than the untreated check (Table 1).

In 1975 Dare yielded more than Hood in 1973 even though nematode pressure was apparently higher (Table 1). DBCP alone did not result in higher yields. Yields from plots treated with DBCP + oxydisulfoton; DBCP + fertilizer; DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb; DBCP + benomyl and maneb + oxydisulfoton; DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb + fertilizer; and DBCP + benomyl and maneb + oxydisulfoton + fertilizer were all higher ($P = 0.05$) than those of the untreated control. One treatment—fungicides + herbicides + fertilizer—yielded less ($P = 0.05$) than the untreated control. Again, all plots treated with nematicide yielded higher ($P = 0.05$) than all plots not receiving DBCP.

Pickett, the resistant cultivar in 1975, yielded less than Dare, the susceptible cultivar (Table 1). In fact, yields from all but one Pickett treatment were less than the untreated susceptible, and some significantly ($P = 0.05$) so. In 1977 apparent differences were not significant (Table 2). The nematode population level was too low to be damaging (Table 2).

DISCUSSION

Treatment with DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb + oxydisulfoton + fertilizer did not produce the highest yield on either the susceptible or the resistant cultivar in 1973 or 1975. The highest yield for the susceptible cultivar was on plots treated with DBCP + benomyl and maneb + trifluralin, linuron, and dinoseb + oxydisulfoton. There is no explanation for the low yield when fertilizer was added to the combination that produced the highest yield (Table 1).

Yields of the susceptible Dare were higher in 1975 than those of the resistant cultivar Pickett. This emphasizes the need for identification to race of the nematode involved.

Yields of Hood were particularly low in 1973, but application of DBCP and certain other pesticides reduced the stresses enough to improve yields somewhat. Yields of Pickett indicate that the nematode was probably a greater stress factor than the drought that occurred that year. On the other hand, low nematode stress in 1977 plus irrigation resulted in yields that were not affected by any treatment or cultivar.

In conclusion, nematicides can increase soybean yields if *H. glycines* population densities are above the economic threshold. Herbicides are beneficial when weed pressures are above threshold levels, and fungicides can reduce damage from foliar diseases when environmental conditions are right for foliar and stem diseases to proliferate (5). Fertilizer increases yield on nutrient-deficient soils. Putting all of these together does not necessarily produce yields that might be expected. Each nematode-infested field must be considered separately before pesticides and fertilizer are used indiscriminately.

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