RESPONSE OF SOYBEANS AND NEMATODES TO AT-PLANTING APPLICATIONS OF FUMIGANT AND NONFUMIGANT NEMATICIDES. [RESPUESTA DE SOJAS Y NEMATODOS A LA APLICACION DURANTE LA SIEMBRA DE NEMATICIDAS FUMIGANTES Y NO FUMIGANTES].

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ABSTRACT

Three fumigant and two nonfumigant nematicides were applied at planting of 'Ransom' soybeans *(Glycine max* (L.) Merr.) to determine their efficacy in controlling *Meloidogyne incognita* (Kofoid and White 1919) Chitwood 1949, *Paratrichodorus (N.) christiei* (Allen, 1957) Siddiqi, 1973, and *Helicotylenchus* sp., and to determine the tolerance of the crop to the nematicides. In the first experiment, ethylene dibromide increased yields and controlled nematodes more effectively than DD and 1,3-D at 9.4, 18.7, 28.1 and 37.4 l/ha injected 20 cm deep, two chisels per row spaced 25 cm apart. In the second experiment, DD at 46.8, 65.5, and 93.5 l/ha and ethylene dibromide at 18.7 l/ha were about equally effective in increasing soybean yields and decreasing nematode populations. Treatments were not phytotoxic in either experiment. Root-knot indices of soybeans in plots treated with phenamiphos and aldicarb applied in the seed furrow and in an 18-cm-wide band ahead of the planter presswheel were significantly less than in plots treated with the same materials applied in a 30-cm-wide band and incorporated ahead of the planter. Yields, however, did not differ significantly among treatments. Phytotoxic symptoms occurred in phenamiphos treated plots where phenamiphos was applied in the seed furrow and in the 18-cm-wide band, but plant stands were not affected.
Key Words: root-knot nematodes, stubby root nematodes, spiral nematodes.

INTRODUCTION

There are two general classes of soil nematicides, fumigants and nonfumigants, available for control of nematodes of soybeans. The fumigants are used only as preplant treatments because they have been considered highly phytotoxic and unsafe to use as at-planting treatments (1). However, recent reports (2,5,6,8) indicated that soybeans in the southern states may be more tolerant to the fumigants, DD (chlorinated C_3 hydrocarbons including 1,3-dichloropropene, 1,2-dichloropropane, other related chlorinated hydrocarbons), 1,3-dichloropropene and related chlorinated C_3 hydrocarbons), and ethylene dibromide (1,2-dibromoethane) than previous reports indicated. Application at planting is usually preferred because it may eliminate an additional operation. The nonfumigant nematicides can usually be applied safely at planting, but they are usually less effective than the fumigants (4,7). Improved application methods are needed to increase the effectiveness of the nonfumigants. For these

reasons, field experiments were conducted to determine safe acceptable rates for application of fumigants at planting, to develop more effective methods of applying nonfumigants, and to compare the fumigants and nonfumigants.

MATERIALS AND METHODS

Three tests were conducted at Tifton, Georgia on a Fuquay loamy sand (88% sand, 8% silt, and 4% clay) infested with *Meloidogyne incognita* (Kofoid and White) Chitwood, *Paratrichodorus (N) christiei* (Allen, 1957) Siddiqi, 1973, and *Helicotylenchus* sp. Chemicals and methods of application used in these tests were as follows: In test no. 1, (Table 1), ethylene dibromide, DD, and 1,3-D at four rates were injected 20 cm deep, two chisels per row spaced 25 cm apart. Phenamiphos (ethyl 4-(methylthio)-*m*-tolyl isopropylphosphoramidate) at one rate was applied in a 30-cm-wide band over the row and rototilled 8-10 cm deep to serve as a standard. In test no. 2 (Table 2), ethylene dibromide at one rate and DD at three rates were injected as above. In test no. 3, (Table 3), aldicarb (2-3methyl-2-(methylthio) propionaldehyde *0*-(methylcarbamoyl)oxime) at three rates and phenamiphos at one rate were applied in the seed furrow. Phenamiphos at two rates and aldicarb at one rate were applied in an 18-cm-wide band behind the seed chute and ahead of the presswheel. Aldicarb and phenamiphos at one rate were applied in a 30-cm-wide band over the row and rototilled 8-10 cm deep. Ethylene dibromide at one rate was injected as above. An untreated control was included in each test.

The experimental design was a randomized complete block replicated either four times (test nos. 2,3) or five times (test no. 1). Plots were 6.1 m long with four rows each spaced 0.9 m apart. The soil was turned 25 cm deep and a subsoil chisel was run 36 cm deep under the row. Treatments were applied and seeds of 'Ransom' soybean were planted on 17 and 18 May. Seeding rate was approximately 10 viable seeds per 30 cm of row. The soil temperature at the 10-cm depth during this 2-day period was 22 C minimum and 34 C maximum. The soil moisture at planting was as follows: test no. 1, 5.6%; test no. 2, 8.2%; and test no. 3, 6.7%. Fertilizer was applied as indicated by soil tests. The herbicide Trifluralin (a,a,a-trifluoro-2,6 dinitro-N,N-dipropyl-P-toluidine) was applied at 0.56 kg a.i./ha and incorporated with a power driven rototiller after subsoiling and before planting. The plots were cultivated to control weeds not controlled with the herbicide. Insecticides were applied as needed. The first significant rainfall after planting occurred on 24 May when 2.0 cm fell. Adequate rainfall occurred throughout the growing season except during August and September. The plots were irrigated with about 2.8 cm of water on 17 August (20 August for test no. 1) and on 11 September.

Stand counts were made on 5 July from a randomly selected 1 m section of each of the two inside rows. Roots of 10 plants from the two outside rows of each plot were rated for severity of galling on 28 August. Root-knot ratings were based on a 1-5 scale: 1 = no galling, 2 = 1-25%, 3 = 26-50%, 4 = 51-75% and 5 = 76-100% of root systems galled. Soil samples were collected on 17 October from the two center rows of each plot, and nematodes were extracted by the centrifuge-sugar-flotation method and then counted (3). Soybean yields and plant height were obtained from the two center rows of each plot. Data were subjected to analysis of variance and Duncan's multiple range test (9). Differences discussed in the following sections will be at the 5% level of probability unless otherwise indicated.

RESULTS AND DISCUSSION

Test no. 1 - All ethylene dibromide treatments and the 1,3-D treatment at 37.4 l ha

Table 1. Effects of rates of three fumigant nematicides and phenamiphos on yield, height, and root-knot indices of soybean and nematode populations. [x]

Treatment & formulation	Rate (l/ha)	Yield (kg/ha)	Height (cm)	Root-knot Index	Number of nematodes/150 cm^3 soil		
					Meloidogyne incognita larvae	*Paratrichodorus christiei*	*Helicotylenchus* spp.
Ethylene dibromide 90 EC	37.4	2863 a	86 a	1.1 b	91 c	120 a	21 de
Ethylene dibromide 90 EC	18.7	2675 a	86 a	1.5 b	216 bc	168 a	3 e
Ethylene dibromide 90 EC	28.1	2574 a	86 a	1.3 b	157 c	144 a	0 e
1,3-D 92L	37.4	2365 ab	85 a	3.2 a	568 a-c	174 a	138 b-e
Ethylene dibromide 90 EC	9.4	1949 bc	75 b-d	1.8 b	413 bc	178 a	13 de
1,3-D 92L	28.1	1626 cd	75 b-d	3.5 a	626 a-c	107 a	176 a-d
1,3-D 92L	18.7	1579 cd	79 b	3.6 a	896 a-c	114 a	134 b-e
DD 100L	28.1	1512 cd	76 bc	3.7 a	1261 a	118 a	194 a-c
Phenamiphos 15G	2.8[y]	1505 cd	74 cd	1.8 b	656 a-c	107 a	21 de
DD 100L	9.4	1398 c-e	76 bc	3.6 a	651 a-c	125 a	334 a
DD 100L	37.4	1364 de	76 bc	3.4 a	852 a-c	88 a	51 c-e
DD 100L	18.7	1270 de	74 cd	3.2 a	507 a-c	85 a	333 a
Control		1257 de	72 cd	3.6 a	978 ab	138 a	219 a-c
1,3-D 92L	9.4	860 e	71 d	3.3 a	842 a-c	67 a	245 ab

[x] Data followed by the same letter in columns are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

[y] Kg/ha

Table 2. Effects of one rate of ethylene dibromide and three rates of DD on yield, height, and root-knot indices of soybean and nematode populations.[x]

Treatment & formulation	Rate (l/ha)	Yield (kg/ha)	Height (cm)	Root-knot index	Number of nematodes/150 cm^3 soil		
					Meloidogyne incognita larvae	*Paratrichodorus christiei*	*Helicotylenchus* sp.
DD 100 L	93.5	2923 a	94 a	1.3 c	48 b	118 a	16 b
Ethylene dibromide 90 EC	18.7	2916 a	94 a	1.1 c	66 b	106 a	2 b
DD 100 L	46.8	2822 a	95 a	2.0 ab	148 b	108 a	4 b
DD 100 L	65.5	2782 a	92 a	1.5 bc	412 ab	148 a	6 b
Control		2412 b	88 a	2.4 a	890 a	158 a	296 a

[x] Data followed by the same letter in columns are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Table 3. Effects of rates and methods of applying nematicides on yield, height, and root-knot indices of soybean and nematode populations. [x]

Treatment & formulation	Rate (kg/ha)	Method of Application	Yield (kg/ha)	Height (cm)	Root-knot Index	Number of nematodes/150 cm^3 soil		
						Meloidogyne incognita larvae	*Paratrichodorus christiei*	*Helicotylenchus* spp.
Ethylene dibromide 90 EC	14.0[y]	inject	2554 a	91 a	2.9 b	1390 a-c	296 a	4 b
Phenamiphos 15G	1.7	seed furrow	2191 a	88 ab	2.6 bc	1488 a-c	272 ab	26 b
Aldicarb 15G	1.1	seed furrow	2164 a	90 ab	2.0 cd	1346 a-c	162 ab	74 ab
Phenamiphos 15G	2.8	18 cm band	2029 a	88 ab	1.9 cd	648 c	162 ab	10 b
Aldicarb 15G	2.2	18 cm band	2016 a	87 ab	1.7 d	1648 a-c	148 b	98 ab
Aldicarb 15G	2.2	30 cm band	1982 a	89 ab	4.1 a	1924 a-c	210 ab	40 b
Phenamiphos 15G	2.2	18 cm band	1915 a	86 ab	2.6 bc	948 b-c	206 ab	6 b
Control			1902 a	85 b	4.1 a	2748 ab	212 ab	104 ab
Aldicarb 15G	0.6	seed furrow	1882 a	89 ab	2.1 cd	2160 a-c	250 ab	172 a
Aldicarb 15G	0.8	seed furrow	1801 a	88 ab	2.1 cd	2162 a-c	220 ab	74 ab
Phenamiphos 15G	2.2	30 cm band	1680 a	85 b	3.8 a	2094 a-c	204 ab	68 ab

[x] Data followed by the same letter in columns are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

[y] l/ha.

produced soybean yields significantly greater than the control (Table 1). The yield of plots treated with ethylene dibromide at 9.4 l/ha, however, was less than yields of plots treated with higher rates of this material. Ethylene dibromide at 37.4 l/ha produced 128% more soybeans than the control. Yields of the 8 other treatments were not significantly different from those of the control. Plants in plots treated with 18.7, 28.1 and 37.4 l/ha of ethylene dibromide and 37.4 l/ha of 1,3-D were taller than plants in all other treatments. The 18.7 l/ha rate of 1,3-D was the only other treatment with plants taller than those in the control. No treatment was phytotoxic or reduced stands (data not shown).

Root-knot galling was less severe in plots treated with the 4 rates of ethylene dibromide and phenamiphos than in all other plots. Only plots treated with 28.1 and 37.4 l/ha of ethylene dibromide contained fewer *M. incognita* larvae than the control. There were fewer *Helicotylenchus* sp. in the soil in plots treated with the 4 rates of ethylene dibromide and phenamiphos than in control plots, but numbers of *P. christiei* did not differ among treatments. Yields were positively correlated ($P = 0.01$) with plant height ($r = 0.88$) and negatively correlated ($P = 0.01$) with number of *M. incognita* larvae in the soil ($r = -0.29$), and root-knot index ($r = -0.59$)

Test no. 2 - Yields of all treated plots were greater than that of control plots (Table 2). Differences among the chemical treatments were not significant. Plots treated with 93.5 l/ha of DD yielded 21% more than control plots. Plant height differences were not significant. Treatments were not phytotoxic and stands were not reduced (data not shown).

All treatments except 46.8 l/ha of DD reduced root-knot galling and all treatments except 65.5 l/ha of DD reduced the number of *M. incognita* larvae in the soil. Populations of *Helicotylenchus* sp. were reduced by all treatments whereas populations of *P. christiei* were not affected. The number of *M. incognita* larvae in the soil was negatively correlated ($P = 0.01$) with yields ($r = -0.75$).

Test no. 3 - Yield differences were not significant; however, yields ranged from 1680 kg/ha for phenamiphos at 2.2 kg a.i./ha applied in a 30-cm-wide band to 2554 kg/ha for ethylene dibromide injected at 4.0 l/ha (Table 3). Plants that received 14.0 l/ha of ethylene dibromide in Table 3 were taller than the control plants, but they were not taller than plants in the other treatments. Leaf necrosis of seedlings, indicating light phytotoxicity, occurred in plots treated with phenamiphos in the seed furrow and in the 18-cm-wide band. Stands did not differ among treatments (data not shown).

Root-knot indices in all treatments were less than for control except in plots treated with aldicarb and phenamiphos 2.2 kg a.i./ha applied in a 30-cm-wide band. Only phenamiphos 2.8 kg a.i./ha applied in an 18-cm band had fewer *M. incognita* larvae than the control. The numbers of *P. christiei* and *Helicotylenchus* sp. in the soil in treated plots were not significantly different from the numbers in control plots. Yields were negatively correlated with root-knot index ($P = 0.01$) ($r = -0.55$) and number of *M. incognita* larvae in the soil ($P = 0.05$) ($r = -0.34$).

CONCLUSIONS

These data indicate that the maximum rates of ethylene dibromide (37.4 l/ha), DD (93.5 l/ha) and 1,3-D (37.4 l/ha) used are not phytotoxic when injected at planting under the conditions of these experiments. Minimum rates at which effective control was obtained were: ethylene dibromide, 18.7 l/ha; DD, 46.8 l/ha; and 1,3-D, 37.4 l/ha. Phenamiphos and aldicarb reduced root-knot indices more effectively when applied in the seed furrow and when applied in an 18-cm-wide band ahead of the planter presswheel than when applied in a 30-cm-wide band and incorporated 8-10 cm

deep. Phytotoxity, however, occurred with phenamiphos applied in the seed furrow and in an 18-cm-wide band ahead of the planter presswheel.

RESUMEN

Tres nematicidas fumigantes y 2 no fumigantes se aplicaron durante la siembra de sojas "Ransom" *(Glycine max* (L.) Merr.) con el proposito de determinar su eficacia en el control de *Meloidogyne incognita* (Kofoid & White) Chitwood, *Paratrichodorus (N) christiei* (Allen, 1957) Siddiqi, 1973, y *Helicotylenchus* sp. y el grado de tolerancia en las sojas. En el experimento inicial dibromuro de etileno aumentó el rendimiento y controló los nematodos con más eficacia que el DD y el 1,3-D aplicado en cantidades de 9.4, 18.7, 28.1 y 37.4 l/ha inyectadas a 20 cm de profundidad con dos inyectores por surco separados 25 cm. En el segundo experimento, DD aplicado en cantidades de 46.8, 65.5 y 93.5 l/ha y dibromuro de etileno a 18.7 lb/ha resultaron igualmente efectivos en aumentar el rendimiento de sojas y reducir la población de nematodos. Ninguno de los tratamientos en ambos experimentos resultó fitotóxico. Los índices de nodulación en los plantíos de sojas en los cuales phenamiphos y aldicarb se aplicaron en el surco y en una banda de 18 cm de ancho en frente del "disco" de la sembradora fueron significantemente menores que en los sembrados tratados con los mismos nematicidas, pero aplicados en una banda de 30 cm de ancho e incorporada en frente de la sembradora. No obstante, no se observó una diferencia significantiva entre los tratamientos. Síntomas fitotóxicos ocurrieron en sembrados en los cuales phenamiphos se aplicó en el surco y en una banda de 18 cm de ancho, pero las plantas no fueron afectadas.

LITERATURE CITED

1. Cristie, J. E. 1959. Plant Nematodes, their Bionomics and Control. The H. & W. B. Drew Company, Jacksonville, Florida. 256 pp; *2.* Blackmon, C. W., and S. A. Lewis. 1979. Nematropica 9:3-7; *3.* Jenkins, W. R. 1964. Plant Dis. Rep. 48:692; *4.* Kinloch, R. A. 1974. J. Nematol. 6:7-11; *5.* Kinloch, R. A. 1979. Nematropica 9:27-32; *6.* Minton, N. A. and M. B. Parker, 1979. Nematropica 9:36-39; *7.* Minton, N. A., M. B. Parker, O. L. Brooks, and C. E. Perry. 1976. Ga. Agric. Res. Bull. No. 189. 19 pp; *8.* Rodríguez-Kábana, R., H. W. Penick, P. S. King, F. A. Gray, E. L. Carden, N. R. McDaniel, F. B. Selman and H. W. Ivey. 1979. Nematropica 9:61-66; *9.* Steel, R. G. D., and J. D. Torrie. 1960. Principles and Procedures of Statistics. McGraw Hill Book Co. Inc. New York. 481 pp.

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