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CONTROL OF NEMATODES ON SOYBEANS WITH PLANTING-TIME APPLICATIONS OF ETHYLENE DIBROMIDE [COMBATE DE NEMATODOS EN LA SOYA CON APLICACIONES EN LA SIEMBRA DE BIBROMURO DE ETILENO]. R. Rodríguez-Kábana, H. W. Penick, and P. S. King, Department of Botany and Microbiology; F. A. Gray, Auburn University Cooperative Extension Service; E. L. Carden, N. R. McDaniel, and F. B. Selman, Gulf Coast Substation at Fairhope; and H. W. Ivey, Wiregrass Substation at Headland; Auburn University, Agricultural Experiment Station, Auburn, Alabama 36830, U.S.A.

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ABSTRACT

Planting-time applications of ethylene dibromide (Soilbrom®90EC) and a mixture of ethylene dibromide (EDB) containing 27% (w/w) chloropicrin (Terr-O-Cide® 72-27) were compared with DBCP (1,2-dibromo-3-chloropropane) for effectiveness against *Meloidogyne arenaria (Neal) Chitwood, M. hapla* Chitwood, and race three of *Heterodera glycines* Ichinohe on soybeans*(Glycine max* (L.) Merr.). Field tests conducted at three different locations in Alabama demonstrated that the two formulations of EDB were as effective as DBCP in controlling the parasite and in incrementing yields of Bragg or Ransom soybeans. No phytotoxicity was detected from planting applications of EDB containing fumigants at rates of 37.41 L/ha or below.
Key words: root-knot and soybean cyst nematodes, halogenated hydrocarbons, trichloronitromethane, tear gas, methods of application, nematicides.

INTRODUCTION

Recent actions by the U. S. Environmental Protection Agency have restricted the use of DBCP (1,2-dibromo-3-chloropropane) on soybeans *(Glycine max* (l.) Merr.) to a degree that it can no longer be considered for practical use on the crop. In the past

DBCP has provided an inexpensive (U.S. $ 15-20/ha) means of controlling nematodes parasitic on soybeans. While other nematicides can be used for this purpose (2,4,7) they are either not cleared for commercial use, or they are too expensive because of the amounts required to attain effective control. Ethylene dibromide (EDB) is one of the oldest nematicides available for commercial use. Its use on soybeans has not been explored, probably because of the general availability of DBCP and early reports that the latter nematicide was 2-3 times more effective than EDB (3). Since EDB is produced at costs comparable to those for DBCP manufacture we thought that this fumigant could be an adequate substitute for DBCP on soybeans. This paper presents results of experiments conducted during the 1978 season to determine the feasibility of using a formulation of EDB (Soilbrom® 90 EC) and a mixture of EDB with 27% (w/w) chloropicrin (Terr-O-Cide® 72-27) at planting time for control of nematodes parasitic of soybeans.

MATERIALS AND METHODS

Tests were conducted in three different locations in Alabama. At the Gulf Coast substation near Fairhope, a test with Bragg soybeans was established in a field with a silt loam infested with *Meloidogyne arenaria* (Neal) Chitwood as the principal parasitic nematode and low numbers of *Helicotylenchus dihystera* (Cobb) Sher and *Trichodorus christiei* Allen. Soilbrom 90 EC was applied at rates of 0, 2.33, 4.67, 9.35, 14.03, 18.70, 23.38, 28.06, and 37.41 L/ha using two chisels per row separated 25.4 cms apart. A treatment of 9.35 L/ha of DBCP 86 EC (Fumazone® 86 EC) was also included for comparison. Each treatment was represented by eight plot replications arranged in a randomized complete block design. Plots were two rows (96.5 cms) wide and six meters long.

A second test with Ransom cultivar was conducted in the vicinity of Summerdale at the Engel farm in a field with a loamy sand heavily infested with race three of *Heterodera glycines* Ichinohe and a low level of infestation of *M. arenaria*. The test included Soilbrom 90 EC at rates of 9.35, 14.03, 18.70, 23.38, 28.06, and 37.01 L/ha and Terr-O-Cide 72-27 at the same rates. A treatment with DBCP 86 EC at 9.35 L/ha and an untreated control were also included. Statistical design, method of application of the fumigants, and size of plots were as described for the Fairhope test.

A third test, a duplicate in design and details of the Summerdale test, was established in the Wiregrass substation near Headland, in a field with a sandy loam moderately infested with *M. hapla* Chitwood (less that ten larvae/50 cm^3 soil). Chisel spacing chosen for this test was 20.3 cms instead of the 25.4-cm spacing used in the other two tests.

Soil samples for nematode analyses were collected in late August (Headland) or in mid-September (Fairhope and Summerdale) to coincide with maximal population development of the parasites (1). Fifteen to 20 soil cores were obtained from every plot using a standard 2.54-cm diam soil probe to a depth of 15 to 20 cms in the root zone. The cores from a plot were composited and a 50 cm^3 subsample taken for extraction of nematodes with a modified flotation sieving technique (6).

Subjective appearance of plots was determined for the Summerdale test two months after planting using a scale where 1 represented plots with soybeans showing poor, stunted growth with some chlorotic foliage and 5 represented plots with plants showing excellent growth with normal green color. Yield in all tests was collected from the entire plots.

Data were analyzed following standard procedures for analyses of variance (8). Values for the least significant differences (LSD) were also calculated following standard procedures and are included in the data tables. Unless otherwise specified all differences referred to in the text were significant to the 5% or lower level of probability.

RESULTS AND DISCUSSION

Data from the Fairhope test indicate (Table 1) that all Soilbrom 90 EC applications reduced populations of *H. dihystera.* These reductions were somewhat proportional to the amount of fumigant applied in the range of 2.33 to 23.38 L/ha. However, differences between treatments in the range of 14.03 L/ha or higher were not significant. DBCP 86 EC at 9.35 L/ha significantly reduced populations of *H. dihystera* to about the same level attained with the same rate of Soilbrom 90 EC. Populations of *T. christiei* or of *M. arenaria* larvae were reduced only with Soilbrom 90 EC treatments of 23.38 L/ha or higher. Yield increases in response to applications of Soilbrom 90 EC were most pronounced in the range of 2.33 to 18.70 L/ha. Small but significant yield gains over those obtained with the 18.70-L rate were evidenced with the use of either 28.06 or 37.41 L/ha of the fumigant. Yield differences between the 9.35-L rate of Soilbrom 90 EC and the DBCP 86 EC treatment were not significant. The use of Bragg, a cultivar with some degree of tolerance to *M. arenaria,* should have resulted in higher yields for the control. However, previous work by the senior author (7) and others (2,4) have shown that this degree of tolerance as measured by yield response is limited and that significant yield increases can be obtained by the use of nematicide treatments on resistant cultivars. Our results also suggest that in heavily infested fields levels of Soilbrom 90 EC of 18.70 to 23.38 L/ha are necessary to maintain larval populations of *M. arenaria* significantly below those in the control and that this practice results in profitable yield responses.

Results from the Wiregrass test showed (Table 2) that larvae of *M. hapla* were present at lower levels than corresponding numbers for *M. arenaria* in the Fairhope test. These data showed that, while significant reductions in numbers of larvae were obtained with some rates (23.38 L/ha or higher) of Soilbrom 90 EC and all rates of Terr-O-Cide 72-27 except one (14.03 L/ha), no clear pattern of response to the treatments

Table* 1. Effect of ethylene dibromide (Soilbrom 90 EC) on yield of Bragg soybeans and nematode control in a test at the Gulfcoast substation, Fairhope, Alabama during the 1978 season.

Treatments	Liters per Hectare	Nematodes per 50 cm^3 soil *H. dihystera*	*T. christiei*	*M. arenaria* (larvae)	Yield (kgs/ha)
Control		42	14	158	831
Soilbrom 90 EC	2.33	24	15	148	1162
Soilbrom 90 EC	4.67	17	16	130	1248
Soilbrom 90 EC	9.35	13	15	140	1383
Soilbrom 90 EC	14.03	8	11	118	1766
Soilbrom 90 EC	18.70	8	12	112	2445
Soilbrom 90 EC	23.38	3	7	38	2549
Soilbrom 90 EC	28.06	6	8	54	2688
Soilbrom 90 EC	37.41	3	6	43	2809
DBCP 86 EC	9.35	17	20	170	1306
LSD (p: 0.05)		8	7	65	235
LSD (p: 0.01)		11	10	86	313

*Figures for variables are averages of eight replications.

Table 2. Effect of ethylene dibromide (Soilbrom 90 EC) and a mixture of ethylene dibromide containing 27% (w/w) chloropicrin (Terr-O-Cide 72-27) on yield of Ransom soybeans and control of *Meloidogyne hapla* in a test at the Wiregrass substation, Dothan, Alabama, conducted during the 1978 season.

Treatments	Liters per Hectare	Larvae per 50 cm³ of Soil	Yield (Kgs/ha)
Control		18	1869
Soilbrom 90 EC	9.35	12	2835
Soilbrom 90 EC	14.03	14	3220
Soilbrom 90 EC	18.70	17	2967
Soilbrom 90 EC	23.38	9	3019
Soilbrom 90 EC	28.06	8	3014
Soilbrom 90 EC	37.41	10	3144
Terr-O-Cide 72-27	9.35	9	2205
Terr-O-Cide 72-27	14.03	18	3290
Terr-O-Cide 72-27	18.70	10	3309
Terr-O-Cide 72-27	23.38	8	3402
Terr-O-Cide 72-27	28.06	10	3345
Terr-O-Cide 72-27	37.41	6	3204
DBCP 86 EC	9.35	9	2233
LSD (p: 0.05)		7	464
LSD (p: 0.01)		10	613

*Figures for variables are averages of eight plot replications.

was evident. This lack of pattern is interpreted as due to the lower level of nematodes present in the test. Similarly, there was no pattern in yield response. With exception of one treatment (Terr-O-Cide 72-27 at 9.35 L/ha) all applications containing EDB increased yields significantly above the control but again there was no relation between yield response and the amount of fumigant applied: 9.35 L/ha of Soilbrom 90 EC or 14.03 L/ha of Terr-O-Cide 72-27 provided significant maximal yield response. The DBCP treatment reduced larval numbers to a significant lower level but did not result in a significant yield increase. Analyses of the data as a factorial experiment indicated a significant advantage in yield response for the use of Terr-O-Cide 72-27. This is perhaps due to control by chloropicrin of some undetected soilborn fungal pathogen, against which this fumigant is active (5). Yield response obtained in this experiment to treatment for control of this low level of infestation reflects the lack of nematode resistance in the Ransom cultivar. Very likely if a more tolerant cultivar such as Bragg had been used yield responses would not have been as great.

Results from the test at Summerdale indicate (Table 3) that none of the treatments reduced larvae of *H. glycines* to significant levels below the control. Some treatments (Soilbrom 90 EC at 18.70 L/ha and Terr-O-Cide 72-27 at 23.38 L/ha) produced larval numbers significantly higher than for the control. These results are probably a reflection of the high level of infestation of *H. glycines* in this field. At the time of sampling, plants in control plots were either dead or very severely stunted and their root systems were destroyed or were very restricted. This probably resulted in a drop in larval numbers for lack of feeding sites. Plots treated with the fumigants had healthier plants,

Table 3. Effect of ethylene dibromide (Soilbrome 90 EC) and a mixture of ethylene dibromide with 27% (w/w) chloropicrin (Terr-O-Cide 72-27) on yield of Ransom soybeans and *Heterodera glycines* (race 3) in a test in the vicinity of Summerdale, Alabama, during the 1978 season.

Treatments	Liters per Hectare	Larvae per 50 cm³ Soil	Subjective** Appearance	Yields (Kgs/ha)
Control		18	1.9	232
Soilbrom 90 EC	9.35	29	2.9	494
Soilbrom 90 EC	14.03	22	3.1	668
Soilbrom 90 EC	18.70	43	3.7	812
Soilbrom 90 EC	23.38	34	4.0	985
Soilbrom 90 EC	28.06	33	4.1	1023
Soilbrom 90 EC	37.41	33	4.3	1301
Terr-O-Cide 72-27	9.35	25	3.1	463
Terr-O-Cide 72-27	14.03	25	3.1	444
Terr-O-Cide 72-27	18.70	32	3.4	580
Ter-O-Cide 72-27	23.38	38	3.9	916
Terr-O-Cide 72-27	28.06	31	3.9	834
Terr-O-Cide 72-27	37.41	26	3.7	1375
DBCP 86 EC	9.35	30	2.5	417
LSD (p: 0.05)		20	0.5	181
LSD (p: 0.01)		27	0.6	243

*Figures for variables are average of eight replications.

**Based on a scale where 1 represented very poor growth and 5 excellent growth of soybean plants.

with active root systems that supported larvae of *H. glycines*. Increments in values for subjective appearance of plots and yield responses indicate that both Soilbrom 90 EC and Terr-O-Cide 72-27 probably provided good early season control of the nematode. Yields increased somewhat proportionally to the amount of either Soilbrom 90 EC or Terr-O-Cide 72-27 applied. Results also indicate that these two fumigants were as effective as DBCP in improving plot appearance and yields.

CONCLUSIONS

1. Data from these experiments show conclusively that either Soilbrom 90 EC or Terr-O-Cide 72-27 are good substitutes for DBCP for the control of plant parasitic nematodes on soybeans.

2. While rates of 9.35 L/ha of the two EDB formulations may be sufficient for treatment of fields with low levels (less than 20 larvae/50 cm³ soil) of *Meloidogyne sp.*, fields with high levels of infestation of either *Meloidogyne sp.* or *Heterodera glycines* may require fumigant dosages of 18.70 L/ha or higher to attain maximal yield response.

RESUMEN

La efectividad de inyecciones al suelo de bibromuro de etileno (Soilbrom 90 EC) y de una mezcla de bibromuro de etileno (BDE) que contiene 27% (p/p) de cloropicrina

(Terr-O-Cide 72-27) para combatir *Meloidogyne arenaria, M. hapla,* y la raza tres de *Heterodera glycines* fue comparada con la de DBCP en soya. Resultados de experimentos de campo en tres localidades de Alabama demostraron que las dos preparaciones de BDE fueron tan efectivas como DBCP en el combate de los parásitos y en ragg y Ransom. No se observaron efectos fitotóxicos como resultado de la inyección en la siembra de las dos preparaciones de BDE a niveles de 37.41 o menos L/ha.
Claves: nematodos noduladores y de quiste de la soya, Glycine max, hidrocarburos halogenados.

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EFFICACY OF PLANTING-TIME APPLICATIONS OF 1,3-DICHLOROPROPENE FOR CONTROL OF NEMATODES ON SOYBEANS [EFECTIVIDAD DE TRATAMIENTOS DURANTE LA SIEMBRA CON 1,3-DICLOROPROPENO PARA EL COMBATE DE NEMATODOS EN SOYA].

R. Rodríguez-Kábana, H. W. Penick, P. S. King, Department of Botany and Microbiology; F. A. Gray, Auburn University Cooperative Extension Service; E. L. Carden, N. R. McDaniel, and F. B. Selman, Gulf Coast Substation at Fairhope; Auburn University, Agricultural Experiment Station, Auburn, Alabama 36830, U.S.A.

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ABSTRACT

Two formulations (DD® and Telone II®) of 1,3-dichloropropene were applied at planting time to soybeans *(Glycine max* (L.) Merr.) to determine their efficacy in controlling root knot and cyst nematodes and the tolerance of the crop to the fumigant. Applications of the two formulations at rates of 18.7 to 84.2 L/ha were not phytotoxic to soybeans. DD or Telone II were not as effective for degree of nematode control or in yield response as the standard treatment of DBCP 86 EC (1,2-dibromo-3-chloropropane) at 9.4 L/ha.
Key Words: chemical control, methods of application, halogenated hydrocarbons, Heterodera glycines, Meloidogyne arenaria.