no hubieron síntomas de fitotoxicidad con ninguna de las concentraciones estudiadas. El aumento en el rendimiento y la efectividad contra *M. arenaria* de los tratamientos de postsiembra fueron tan buenos como los obtenidos con el de la siembra sin que se registrasen diferencias significativas entre los de postsiembra. Los resultados señalan que el DBCP puede ser utilizado en el maní a dosis muy inferiores a las de uso corriente sin perder efectivida contra *M. arenaria* o rendimiento, siempre que se efectuen cambios en el método de aplicación de este material al suelo. Los datos obtenidos también sugieren que DBCP tiene propiedades que permiten el uso de técnicas variadas de aplicación para el maní.
Claves: 1,2-dibromo-3-cloropropano, nematodos noduladores, Arachis hypogaea, combate de enfermedades, hidrocarburos halogenados.

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CONTROL OF ROOT-KNOT NEMATODES ON PEANUTS WITH PLANTING TIME AND POSTEMERGENCE APPLICATIONS OF ETHYLENE DIBROMIDE AND AN ETHYLENE DIBROMIDE-CHLOROPICRIN MIXTURE [COMBATE DEL NEMATODO NODULADOR EN EL MANI CON APLICACIONES EN LA SIEMBRA Y LA POSTSIEMBRA DE BIBROMURO DE ETILENO Y DE UNA MEZCLA DE BIBROMURO DE ETILENO CON CLOROPICRINA].

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ABSTRACT

Field studies were conducted during 1977 and 1978 to determine the feasibility of using ethylene dibromide (Soilbrom 90®EC) or an ethylene dibromide-chloropicrin mixture (Terr-O-Cide®72-27) as substitutes for DBCP (1,2-dibromo-3-chloropropane) for control of root-knot nematodes on the Florunner cultivar of peanut *(Arachis*

hypogaea L.). Results from a field heavily infested with root-knot nematodes indicated that planting time applications of Soilbrom 90 EC at 9.35L/ha were as effective as applications of DBCP at the same rate but that higher rates of Terr-O-Cide 72-27 were needed to obtain the same degree of nematode control. Maximal yield responses and best control of root-knot nematode were obtained with rates of 18.70 L/ha with either of the two ethylene dibromide formulations; rates higher than 18.70 L/ha did not produce additional benefits. When Soilbrom 90 EC was applied postemergence at rates of 9.35-37.41 L/ha at the mid-bloom stage of growth, no phytotoxicity was detected. Planting time applications of either Soilbrom 90 EC or Terr-O-Cide 72-27 resulted in better control of root-knot nematodes and higher yields than postemergence applications; planting time applications alone were as effective as treatments that combined planting time followed by mid-bloom applications.
Key Words: nematode control, methods of application, nematicides, halogenated hydrocarbons, Meloidogyne arenaria, M. hapla, trichloronitromethane, tear gas, fumigants.

INTRODUCTION

The peanut plant *(Arachis hypogaea* L.) is subject to attack by several nematode species which cause significant yield losses (1,8,10). The most important parasitic species in Alabama are the peanut root-knot nematode *(Meloidogyne arenaria* (Neal) Chitwood), and to a lesser extent the northern root-knot nematode *(M. hapla* Chitwood) and species of *Pratylenchus* (5,8). Control of these parasites in seriously infested fields has been primarily effected through the use of DBCP (1,2-dibromo-3-chloropropane) at planting time (3). Use of this fumigant resulted in consistently good control of the parasites for a reasonable investment (U.S. $ 17-25/ha). Recent actions by the U.S. Environmental Protection Agency (EPA) have eliminated the use of DBCP on peanuts. Although other contact and systemic nematicides can be used for control of nematodes parasitic on peanuts, these nematicides are either not as effective, or are more expensive, and their correct use on peanuts is still under study (2,4,6,9). Although the fumigant ethylene dibromide (EDB) is one of the oldest nematicides (14) its use on peanuts has been limited because of the general availability of DBCP which was considered to be five times more effective in preliminary trials by McBeth and Bergeson (7). Planting time applications of EDB, and specially of EDB and chloropicrin mixtures, have been thought to be phytotoxic to peanuts, hence recommendations for use were only for preplant application (3). Because EDB, and EDB-chloropicrin mixtures, could provide for acceptable economical treatments for nematode control in peanuts we decided to explore their feasibility. This article presents results of a two-year study on the use of these fumigants on peanuts.

MATERIALS AND METHODS

Tests were conducted in the vicinity of Headland, Alabama, in two fields which had been under peanut culture for at least three years. One field was heavily infested with *M. arenaria* and the other with *M. hapla*. Each treatment in every test was represented by eight plot replications arranged in a randomized complete block design. Plots consisted of two 91.4-cm rows nine m long. All tests were conducted using the Florunner cultivar following recommended cultural practices for southern Alabama.

Planting-time applications of the fumigants were made with a gravity flow apparatus and the materials were injected into the soil to a depth of 20 cm using two chisels per row separated 20 cms apart; postemergence applications were performed similarly in the first week of July at the mid-bloom stage but with the chisels separated

25 cms apart.

Soil samples for nematode analysis were collected during the third week of August to coincide with the period of maximal population development (5). Samples were taken from every plot to a depth of 15-20 cms from the root zone using a standard 2.5-cm diam soil probe. Fifteen cores collected from each plot were composited and a 50 cm^3 subsample was used to extract nematodes with a modified flotation-sieving method (12,13).

The relative appearance of plots was determined in mid-August using a subjective scale where 1 represented plots with plants having poor, unthrifty growth with signs of chlorosis not covering the entire plot surface, and 5 represented plots with plants showing normal green color with vigorous growth that covered the entire plot. Yield was obtained from the entire plot 135 days after planting.

Description of Experiments. Experiments were conducted in 1977 and 1978 to test the relative efficacy of planting time applications of EDB and EDB-chloropicrin against *M. arenaria.* In these experiments EDB was applied as the Soilbrom®90EC formulation and the EDB-chloropicrin mixture was the Terr-O-Cide® 72-27 formulation (72% EDB and 27% chloropicrin by weight). In the 1977 season the fumigant formulations were applied at 0, 4.67, 9.35, 18.70, 28.06, and 37.41 L/ha; rates for the 1978 test were: 0, 9.35, 14.03, 18.70, 28.06, and 37.41 L/ha. In both seasons a treatment with DBCP 86 EC (Fumazone® 86 EC) at 9.35 L/ha was included for comparison.

The relation of chisel spacing to efficacy of Terr-O-Cide 72-27 was studied in 1978 in the field infested with *M. hapla.* The fumigant was applied at planting time at 18.70 L/ha using either a single chisel set 7.6 cms to the side of the seed furrow or with two chisels per row separated 15.2, 20.3, 25.4, 30.5, or 35.6 cms. Controls with no fumigant and a treatment with 18.70 L/ha of Soilbrom 90 EC applied with two chisels per row separated 20.3 cms apart were included for comparisons.

The effect of postemergence applications of Soilbrom 90 EC was tested in the *M. arenaria* field during the 1977 season. The fumigant was applied at 0, 9.35, 18.70, 28.06, and 37.41 L/ha, and a treatment with 9.35 L/ of DBCP was included at planting. The relative efficacy of a planting time application (18.70 L/ha) of Terr-O-Cide 72-27 in comparison with mid-bloom applications (9.35 L/ha) of the fumigant and combined planting and mid-bloom applications was studied in a 1978 experiment in the *M. hapla* field. The experiment included untreated plots and plots that received 18.70 L/ha of Soilbrom 90 EC at planting time.

Statistical Analyses. All data were statistically analyzed following standard procedures for analysis of variance (15). Unless otherwise stated differences referred to in the text were significant at the 5% or lower level of probability. Values for least significant differences (LSD) were also calculated following standard procedures and are included in the Tables of results.

RESULTS AND DISCUSSION

Planting time applications. Soilbrom 90 EC or Terr-O-Cide 72-27 applied at planting during the 1977 season resulted in almost hyperbolic declines in larval numbers of *M. arenaria* (Table 1); sharp declines in numbers occurred in response to applications of 4.67 and 9.35 L/ha followed by almost perfect control of the nematode at rates of 18.70 L/ha or higher of the fumigants. The subjective appearance of plots was significantly improved over that of control plots by the use of either fumigant at rates of 9.35 L/ha or higher; however, differences in appearance between plots treated with those rates were not significant. Yield response to fumigant treatment was inversely related to nematode numbers. Thus, after a sharp rise in response to the 4.67 and 9.35 L

Table 1. Effect of planting time applications of Soilbrom 90 EC and Terr-O-Cide 72-27 on *M. arenaria* populations and yields of Florunner peanuts in 1977 and 1978.

Treatments	L/ha	Larvae/ 50 cm^3 Soil		Subjective Appearance		Yield (Kgs/ha)	
		1977	1978	1977	1978	1977	1978
Control		34.1	33.1	2.3	2.7	1932	2268
Soilbrom 90 EC	4.67	18.4	--	4.2	--	3881	--
Soilbrom 90 EC	9.35	9.1	10.1	4.5	3.1	4372	2948
Soilbrom 90 EC	14.03	--	4.9	--	3.1	--	3121
Soilbrom 90 EC	18.70	1.1	3.9	4.6	3.2	4879	3486
Soilbrom 90 EC	28.06	0.0	2.2	4.6	3.0	4735	3032
Soilbrom 90 EC	37.41	0.6	3.0	4.5	3.3	4516	3393
Terr-O-Cide 72-27	4.67	14.2	--	3.4	--	3027	--
Terr-O-Cide 72-27	9.35	20.1	45.7	4.6	3.1	3811	2541
Terr-O-Cide 72-27	14.03	--	12.0	--	3.5	--	3423
Terr-O-Cide 72-27	18.70	0.5	8.0	4.6	3.1	4665	3098
Terr-O-Cide 72-27	28.06	0.6	1.5	4.7	3.4	4790	3583
Terr-O-Cide 72-27	37.41	0.1	1.2	4.6	3.1	4611	3295
DBCP 86 EC	9.35	8.6	3.7	4.5	3.5	3732	3167
LSD (p:0.05):		17.1	18.5	0.5	0.6	538	629
LSD (p:0.01):		23.4	24.6	0.6	0.8	712	833

*Figures for variables are averages of eight plot replications.

**Subjective appearance of plots based on a scale where 1 represented very poor growth and 5 excellent growth.

treatments, maximal yields were obtained with rates of 18.70 L or higher; yield differences between treatments with 18.70 L or higher of the fumigants were not significant. The performance of Soilbrom 90 EC (at 9.35 L/ha) compared with DBCP was superior with respect to yield response but was similar for degree of nematode control or for subjective appearance of plots. Results also indicated that Terr-O-Cide 72-27 (at 9.35 L/ha) was inferior to DBCP for yield response and degree of nematode control but that this treatment resulted in similar subjective appearance values as the DBCP treatment.

Data from the 1978 test (Table 1) indicated that planting-time applications of Soilbrom 90 EC or Terr-O-Cide 72-27 at rates of 14.03 L/ha or higher resulted in significant reductions in larval populations of *M. arenaria* and maximal yield increments; differences in degree of control or yield response between these rates were not significant. Soilbrom 90 EC at the 9.35 L/ha rate significantly increased yield and reduced larval populations but Terr-O-Cide 72-27 failed to reduce larval populations and did not increase yields above the control. Although some improvement in the subjective appearance of plots was noted with the use of the two fumigants, differences between treatments were not sharp, a fact attributed to the dry conditions prevalent during the last 45 days of the season when the plots were rated.

Results from these experiments suggest the superiority of EDB over EDB-chloropicrin mixtures for control of *M. arenaria*. Chloropicrin is mixed with EDB to provide fungicidal activity to the formulation, since EDB is strictly a nematicidal fumigant (11). Consequently, the use of the more expensive (U.S. $ 3-4/L) Terr-O-Cide 72-27 should be restricted to fields with nematode-fungal complexes. Some difficulty was experienced in the application of Terr-O-Cide 72-27 particularly in the transfer of material prior to delivery in the field; this was due to the lachrymatory properties of chloropicrin (tear gas). Our results indicate that in fields with only nematode problems Soilbrom 90 EC should be given preference. Soilbrom 90 EC proved to be a good substitute for DBCP; the equipment needed for this application is the same as that for DBCP and its price is within an acceptable range (U.S. $ 2-2.6/L).

Table 2. Relation between chisel spacing and effectiveness of planting time applications of (18.70 L/ha) of Terr-O-Cide 72-27* against *M. hapla* in a field experiment with Florunner peanuts during the 1978 season.

Spacing (centimeters)	Larvae per 50 cm^3 Soil	Yield (Kgs/ha)
Control	14.5	3505
Single Chisel	1.1	4355
15.2	0.6	4562
20.3	0.2	4599
25.4	0.5	4497
30.5	3.9	4017
35.6	5.0	4271
Soilbrom 90 EC (18.70 L/ha)	3.2	4470
LSD (p: 0.05):	8.9	390
LSD (p: 0.05):	11.8	521

*Terr-O-Cide 72-27 contains 72% EDB and 27% chloropicrin by weight.
**Figures for variables are average of eight plot replications.

Chisel spacing experiment. Analyses of results from the chisel spacing study (Table 2) indicated that there were no significant differences between the various chisel spacings with respect to nematode control; all treatments reduced numbers of larvae of *M. hapla* below those for the control. However, although yield from all treatments was superior to that of the control, maximal yield responses were obtained with chisel spacings of 15.2, 20.3, or 25.4 cms. These treatments resulted in significantly (p: 0.10) higher yields than those with either the 30.5 or 35.6 cm spacings.

Postemergence treatments. Midbloom applications of Soilbrom 90 EC during the 1977 season did not result in the degree of control obtained with planting time applications of this fumigant (Table 3). The number of larvae of *M. arenaria* in plots treated with 9.35 L/ha was not significantly different from those in control plots. Postemergence rates of 18.70 L or higher resulted in no more than a 64 to 76% control of the nematode. Differences in subjective appearance between control plots and those fumigated were not significant. Yields from Soilbrom-treated plots were not significantly higher than that for the control. None of the postemergence treatments

Table 3. Effect of postemergence applications of ethylene dibromide (Soilbrom 90 EC) on larvae of *M. arenaria,* subjective appearance of plots, and yield of Florunner peanuts in a field experiment during the 1977 season.

Treatment	Liters per Hectare	Larvae per 50 cm^3 Soil	Subjective** Appearance	Yield (Kgs/ha)
Control		58	4.2	3354
Soilbrom 90 EC	9.35	32	4.7	3681
Soilbrom 90 EC	18.70	21	4.7	3542
Soilbrom 90 EC	28.06	14	4.8	4061
Soilbrom 90 EC	37.41	18	4.8	3512
DBCP (at planting)	9.35	2	4.8	4662
LSD (p: 0.05):		37	0.7	759
LSD (p: 0.01):		49	0.9	1004

*Figures for variables are the average of eight plot replications.
**Subjective appearance of plots based on a scale where 1 represented very poor growth and 5 excellent growth.

equaled the degree of control or the yield increments obtained with the planting time treatment of DBCP at 9.35 L/ha.

Postemergence applications of Terr-O-Cide 72-27 at 9.35L/ha during the 1978 season did not result in detectable phytotoxicity to peanuts. However, significant differences in yield response and degree of control of *M. hapla* were evidenced (Table 4). Thus, while all treatments that included the planting time application of Terr-O-Cide 72-27 resulted in near perfect control of the parasite, treatments consisting of only postemergence applications did not reduce numbers of larvae or increase yields. All treatments that combined the planting-time application with postemergence application did not differ significantly in yield response from the 18.70 L planting-time treatment. The evidence thus indicates that a single planting-time application of 18.70 L/ha of the fumigant was the most effective treatment for yield response and nematode control.

Table 4. Effect of planting and postemergence applications of Terr-O-Cide 72-27 on *M. hapla* in a field experiment with Florunner peanuts during the 1978 season.

Treatment	Liters per Hectare		Larvae per 50 cm^3 Soil	Yield (Kgs/ha)
	Planting	Midbloom		
Control			15.5	3558
Terr-O-Cide 72-27	18.70	0.00	0.2	4600
Terr-O-Cide 72-27	0.00	9.35	15.9	3265
Terr-O-Cide 72-27	18.70	9.35	0.9	4340
Soilbrom 90 EC	18.70	0.00	3.2	4470
	LSD (p: 0.05):		9.0	382
	LSD (p: 0.01):		11.8	519

*Figures for variables are averages of eight plot replications.
**Terr-O-Cide 72-27 contains 72% EDB and 27% chloropicrin by weight.

CONCLUSIONS

1. Results indicate that either EDB (Soilbrom 90 EC) or EDB-chloropicrin (Terr-O-Code 72-27) can be used effectively at planting time for control of root-knot nematodes in peanuts without danger to the crop. Maximal yield responses can be expected with rates in the range of 14.03-18.70 L/ha.
2. Soilbrom 90 EC is as effective as DBCP for control of root-knot nematodes in peanuts and is more effective than Terr-O-Cide 72-27.
3. Applications of Terr-O-Cide 72-27 at planting time is most effectively done with a single chisel, or two chisels per row separated 15.2 - 25.4 cms apart.
4. Florunner peanuts can tolerate up to 37.41 L/ha of Soilbrom 90 EC applied at mid-bloom using two chisels per row separated 25.4 cms apart. However, the value of such postemergence applications for control of *M. arenaria* is questionalbe since they did not result in as adequate degree of control or yield response as a planting time application of the fumigant at 18.70 L/ha.
5. Planting time application of Terr-O-Cide 72-27 (18.70 L/ha) was superior to a midbloom-application (9.35 L/ha) of the fumigant for control of *M. hapla* and yield response. A combination of the planting time treatment followed by the mid-bloom application was not any better for controlling *M. hapla* or in yield response than the planting time application alone.

RESUMEN

La posibilidad de substituir DBCP por bibromuro de etileno (Soilbrom 90® EC) o por una mezcla de éste con cloropicrina (Terr-O-Cidec 72-27) para el control de nematodos noduladores del maní Florunner se estudió en las campañas de 1977 y 1978. Resultados obtenidos de experimentos en campos altamente infestados con estos nematodos señalaron que la inyección en la siembra de 9.35 L/ha de Soilbrom 90 EC fue tan efectiva como la equivalente de DBCP, pero que se necesitaron dosis más altas de Terr-O-Cide 72-27 para obtener el mismo grado de combate. Rendimientos máximos y mejor efectividad contra los nematodos se obtuvieron con dosis de 18.70 L/ha o más altas, con cualquiera de las dos preparaciones de bibromuro de etileno. La inyección de postsiembra a media floración del maní de Soilbrom 90 EC en dosis de 9.35 a 37.41 L/ha no resultó en fitotixicidad aparente. El uso de Soilbrom 90 EC o Terr-O-Cide 72-27 durante la siembra dió mejor resultado para el combate de los nematodos y en rendimiento que las inyecciones de postsiembra; el empleo de estos fumigantes durante la siembra fue tan efectivo como tratamientos combinados de siembra y postsiembra con los mismos fumigantes.
Claves: Arachis hypogaea, combate de nematodos, métodos de uso, Meloidogyne arenaria, Meloidogyne hapla, nematicidas.

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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