COMBINATIONS OF 1,3-D AND ALDICARB FOR MANAGEMENT OF *MELOIDOGYNE ARENARIA* IN PEANUTS

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ABSTRACT

Rodríguez-Kábana, R., C. F. Weaver, and P. S. King. 1985. Combinations of 1,3-D and aldicarb for management of *Meloidogyne arenaria* in peanuts. Nematropica 15:93-106.

The efficacy of planting time applications of the fumigant 1,3-D (Telone® II) and the systemic nematicide aldicarb (Temik® 15G) for control of *Meloidogyne arenaria* in 'Florunner' peanut (*Arachis hypogaea*) was studied in a field near Headland, Alabama. Aldicarb was applied at 1.1 and 2.2 kg ai/ha in a 20 cm band with the seed furrow in the middle; 1,3-D was injected to a depth of 25 cm at rates of 17.2, 34.4, and 51.6 L/ha using 2 injectors per row set 20 cm apart with the seed furrow in the middle between the injectors. All possible combination treatments with the 2 nematicides at these rates were also studied. A treatment of 16.8 L/ha of EDB applied as described for 1,3-D was included as a standard. The experiment was conducted in the same field in 1983 and 1984. There was no interaction between the effects of aldicarb and 1,3-D on either yield or soil larval populations of *M. arenaria*. Aldicarb increased yield (Y) in a manner best described by $Y = Ym\text{-}e^{C-kN}$ where k and C are constants, Ym the maximal yield possible, and N the nematicide rate. Yield responses to 1,3-D applications also followed the same type function in 1983; however, in 1984 no clear pattern of response was observed. Larval populations of *M. arenaria* (L) were reduced proportionately to dosages of aldicarb according to $L = A + B/N$, where A and B are constants; this equation also described the response to 1,3-D in 1983. In 1984 larval populations were reduced by 1,3-D in a linear manner. Results indicated that it is possible to equal or surpass the performance of EDB in increasing yields and in control of *M. arenaria* with combination treatments of aldicarb and 1,3-D. Some degree of phytotoxicity was observed each year in response to 1,3-D applications.

Additional key words: pest management, cultural practices, carbamate nematicides, halogenated hydrocarbons, crop losses.

RESUMEN

Rodríguez-Kábana, R., C. F. Weaver, y P. S. King. 1985. Tratamientos combinados de 1,3-D con aldicarb para combatir *Meloidogyne arenaria* en el maní. Nematrópica 15:93-106.

Se estudió la eficacia de applicaciones combinadas en la siembra del fumigante 1,3-D (Telone® II) con el nematicida sistémico aldicarb (Temik® 15G) para combatir *Meloidogyne arenaria* en el maní 'Florunner' (*Arachis hypogaea*) en un campo aledaño a Headland, Alabama. Se aplicó aldicarb en dosis de 1.1 y 2.2 kg i.a./ha en una franja de 20 cm con la sementera en el medio; 1,3-D fue inyectado a una profundidad de 25 cm y en dosis de 17.2, 34.4, y 51.6 L/ha utilizándose para ello 2 inyectores por surco separados

20 cm el uno del otro quedando las semillas en el medio entre los inyectores. Todas las combinaciones posibles entre las dosis descritas para los dos nematicidas fueron estudiadas. También en el experimento se incluyó un tratamiento con EDB a dosis de 16.8 L/ha inyectado en el suelo de la misma forma que el 1,3-D. El experimento se efectuó en 1983 y fue repetido en 1984 en el mismo campo. Las interacciones entre los efectos de los tratamientos con aldicarb y los de los tratamientos con 1,3-D sobre la producción o sobre las poblaciones de larvas de *M. arenaria,* no fueron significativas. Los tratamientos con aldicarb aumentaron el rendimiento (Y) de acuerdo con la ecuación $Y = Ym\text{-}e^{C-kN}$, en la cual k y C son constantes, Ym representa el rendimiento máximo posible y N la dosis del nematicida. Los aumentos en rendimiento como consecuencia de las aplicaciones de 1,3-D también siguieron el mismo modelo pero sólo en 1983; en 1984, no hubo relación definida entre las dosis de 1,3-D y el redimiento de maní. Las poblaciones de larvas de *M. arenaria* (L) disminuyeron como consecuencia de las aplicaciones de aldicarb de acuerdo con la función $L = A + B/N$ en la cual A y B son constantes; esta ecuación tambien definió la relación entre las larvas y las dosis de 1,3-D en 1983 aunque en 1984 la relación entre las dos variables fue de tipo linear. Los resultados del estudio señalan que es posible obtener aumentos de rendimiento y combatir *M. arenaria* al igual o mejor que lo que se obtiene con el uso del EDB. En cado año del estudio se observaron ciertos niveles de fitotoxicidad debidos a los tratamientos con 1,3-D.
Palabras claves adicionales: manejo de plagas, carbamatos, hidrocarburos halogenados, pérdidas de rendimiento.

INTRODUCTION

The peanut (*Arachis hypogaea* L.) is subject to attack by a variety of nematodes (4). Principal among these are the root-knot nematodes, *Meloidogyne* spp. Yield losses to root-knot nematodes can be considerable (11). Control of these nematodes has been based in part on the use of appropriate rotation with non-host or less susceptible plants; however, in heavily infested fields some rotations are not very effective (9). There are no resistant varieties because of a lack of sources of resistance (3). Consequently, control of root-knot nematodes has been based mainly on the use of nematicides. In Alabama the principal root-knot nematode species is *M. arenaria* (Neal) Chitwood which infests over 40% of the peanut acreage (2). In the past, control of *M. arenaria* in Alabama was based on the use of the halogenated hydrocarbons DBCP and EDB. Recent removal of these two fumigant nematicides by regulatory action in the United States created a need to find substitute nematicide treatments. At-plant use of the fumigant 1,3-D has been suggested (5,8) but the performance of this fumigant for control of *M. arenaria* has not been as good as that obtained with DBCP or EDB (unpublished data by the authors). Since combination treatments of systemic nematicides (e.g. aldicarb) and 1,3-D could increase the efficacy of the nematicides against *M. arenaria,* we conducted experiments to evaluate this type of treatment.

MATERIALS AND METHODS

Experiments were conducted at the Wiregrass substation near Headland, Alabama, in a level irrigated field infested with *Meloidogyne arenaria* (Neal) Chitwood. The field had been in peanut for the preceeding 12 years. The soil was a silt loam with pH = 6.2 and organic matter content < 1.0% (w/w). Plots were two rows (each 91 cm apart) wide and 10 m long. There were 8 replications per treatment arranged in a randomized complete block design. 'Florunner' peanuts were maintained in good growing condition by following recommended cultural practices and measures for control of foliar diseases, insects, and weeds (1).

The effect of 1,3-D (Telone® II) and aldicarb (Temik® 15G) on populations of *M. arenaria* and on peanut yield were studied in an experiment conducted in 1983 and repeated in 1984. Treatments consisted of at-plant applications of 1,3-D at rates of 0, 17.2, 34.4, and 51.6 L/ha. The fumigant was injected to a depth of 25 cm using 2 injectors/row set 20 cm apart with the seed furrow in the middle. Aldicarb was applied at-plant at rates of 0, 1.1, and 2.2 kg a.i./ha; the nematicide was delivered in a 20-cm band (7,10) with the seed furrow in the middle and was lightly incorporated (5-cm depth) into the soil. The experiment also contained treatments of the two nematicides applied as described in all possible combinations of the rates used for each nematicide. The experiment also included a treatment with EDB (Soilbrom® 90) applied at 16.8 L a.i./ha as described for the 1,3-D applications. The EDB treatment served as a standard of comparison for the other treatments.

Soil samples for nematode analysis were collected 2 weeks befor harvest to coincide with the period of maximal larval population development (2). Samples were collected from each plot using a standard 2.5-cm-diam probe. A total of 16-20 cores of soil/plot were collected from the root zone to a depth of 18-20 cm in a zig-zag fashion along the center of each plot. The cores for each plot were composited and a 100 cm^3 subsample was used to determine nematode numbers using the "salad bowl" incubation technique (6).

The general appearance of plants in each plot was assessed 10 wk after planting (pegging time) using a subjective scale of 1-5 with 1 representing plants with the worst appearance and 5 those with the best.

Yields were obtained at maturity by harvesting the entire plot. Data were analyzed using standard procedures for analysis of variance; Fisher's least significant differences were also calculated following standard procedures (12). Unless otherwise stated, differences referred to in the text were significant to the 5% or lower level of probability.

RESULTS

1983. Data for individual treatments obtained in 1983 are presented in Table 1. Factorial analysis indicated no interaction between the effects of 1,3-D and aldicarb on yield. The analysis also indicated that the effect of 1,3-D independent of aldicarb on yield was significant and resulted in a positive response to increasing rates of the fumigant (Table 2).

The effect of aldicarb on yield considered independently of the effect of 1,3-D on the variable was positive and significant (Table 3); the greatest response was obtained with the 1.1 kg/ha rate. A small additional increase in yield was obtained in response to the 2.2 kg/ha rate.

There was no significant interaction between the effects of 1,3-D and aldicarb on *M. arenaria* larval populations. All rates of 1,3-D reduced larval populations equally (Table 2) and both rates of aldicarb reduced larval numbers to the same extent (Table 3).

Aldicarb singly or in combination with 1,3-D improved the general appearance of peanut plants. There was no interaction between the effects of 1,3-D and aldicarb on subjective appearance. There was a general decline in appearance index values in response to increasing rates of 1,3-D (Table 2), and a positive response to aldicarb (Table 3).

1984. Data obtained for individual treatments in 1984 are presented in Table 4. Applications of 1,3-D alone resulted in significant yield increases when injected at 34.4 L/ha or higher; at these rates the fumigant reduced larval populations. Both rates of aldicarb increased peanut yields and reduced larval populations. Interactions between 1,3-D and aldicarb on yield or larval populations were not significant. The effects of aldicarb independent of 1,3-D on yield and larval populations are presented in Table 5. Greatest yield response and reduction in larval populations were obtained with the 1.1 kg/ha rate of aldicarb; no additional responses were obtained with the 2.2 kg/ha rate.

The effects of 1,3-D independent of aldicarb on yield and larval populations are presented in Table 6; the fumigant had no effect on yield but reduced larval populations when applied at the two highest rates.

There was a significant interaction between the effects of 1,3-D and aldicarb on subjective appearance index values. Thus, no general conclusions could be drawn on the overall effect of either nematicide on the index.

DISCUSSION

Yield in each of the experiments of the study can be thought of as a function of several components, i.e., f(Y1,Y2,Y3,...,Yn). Also, for each experiment there is a maximal yield possible (Ym), part of which may

Table 1. Effects of at-plant applications of 1,3-D and aldicarb on peanut yields and *Meloidogyne arenaria* in a 1983 field experiment at the Wiregrass substation near Headland, Alabama.

	Aldicarb (kg a.i./ha)								
	0.0			1.1			2.2		
1,3-D (L/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index[x]	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index
0.0	2689	156	3.1	3946	69	4.5	4068	91	4.5
17.2	2604	60	3.0	4153	39	4.3	3995	25	4.2
34.4	3312	121	3.0	3868	39	4.1	4226	16	4.1
51.6	3318	69	3.0	4163	19	3.7	4402	8	3.9
EDB-90 (16.8 L/ha)	4106	8	3.0	—	—	—	—	—	—
LSD (P=0.05)	515	48	0.29	515	48	0.29	515	48	0.29

[x]Index based on a scale of 1-5 where 1 represented plots with the worst looking plants and 5 those with plants in excellent condition.

Table 2. Effects of at-plant applications of 1,3-D on peanut yields, *Meloidogyne arenaria*, and subjective appearance index values, considered independently of the effects of aldicarb on the variables in the 1983 experiment.

1,3-D (L/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil	Subjective appearance index[x]
0.0	3567[y]	105[y]	4.00[y]
17.2	3668	42	3.80
34.4	3803	59	3.75
51.6	3960	32	3.54
LSD (P=0.05):	251	28	0.29

[x]Index based on a scale of 1-5 where 1 represented plots with the worst looking plants and 5 those with plants in excellent condition.
[y]Figures in each column are averages across aldicarb levels.

Table 3. Effects of at-plant applications of aldicarb on peanut yields, *Meloidogyne arenaria*, and subjective appearance index values, considered independently of the effects of 1,3-D on the variables in the 1983 experiment.

Aldicarb (kg ai/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil	Subjective appearance index[x]
0.0	2979[y]	102[y]	3.05[y]
1.1	4033	42	4.15
2.2	4236	35	4.19
LSD (P=0.05):	217	24	0.14

[x]Index based on a scale of 1-5 where 1 represented plots with the worst looking plants and 5 those with plants in excellent condition.
[y]Figures in each column are averages across 1,3-D levels.

Table 4. Effect of at-plant applications of 1,3-D and aldicarb on peanut yields and *Meloidogyne arenaria* in a 1984 field experiment at the Wiregrass substation near Headland, Alabama.

	Aldicarb (kg a.i./ha)								
	0.0			1.1			2.2		
1,3-D (L/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index[x]	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index	Yield (kg/ha)	Larvae per 100 cm^3 soil	Appearance index
0.0	2204	379	4.2	3126	149	4.2	3553	256	4.5
17.2	2478	326	4.0	2902	252	4.3	3736	89	4.5
34.4	3306	178	4.4	3373	101	4.3	3434	111	4.5
51.6	2726	196	4.1	3373	85	4.3	2963	40	3.7
EDB-90 (16.8 L/ha)	3363	184	4.4	—	—	—	—	—	—
LSD (P=0.05)	767	95	0.3	767	95	0.3	767	95	0.3

[x]Index based on a scale of 1-5 where 1 represented plots with the worst looking plants and 5 those with plants in excellent condition.

Table 5. Effects of at-plant applications of aldicarb on peanut yields and *Meloidogyne arenaria,* considered independently of the effects of 1,3-D on the variables in the 1984 experiment.

Aldicarb (kg ai/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil
0.0	2678[x]	269[x]
1.1	3194	147
2.2	3422	124
LSD (P=0.05):	384	48

[x]Figures in each column are averages across 1,3-D levels.

Table 6. Effects of at-plant applications of 1,3-D on peanut yields and *Meloidogyne arenaria,* considered independently of the effects of aldicarb on the variables in the 1984 experiment.

1,3-D (L/ha)	Yield (kg/ha)	Larvae per 100 cm^3 soil
0.0	2961[y]	261[y]
17.2	3039	222
34.4	3371	130
51.6	3021	107
LSD (P=0.05):	N.S.[x]	55

[x]All differences not significant at P=0.05.
[y]Figures in each column are averages across aldicarb levels.

be recovered through the application of nematicides. The rate at which yield increases in relation to the amount of nematicide applied per hectare (dY/dN) can be viewed as depending on the difference between Ym and the individual components of yield,

$$dY/dN = k(Ym\text{-}Y1)\ (Ym\text{-}Y2)\ldots\ldots.(Ym\text{-}Yn) \qquad (I)$$

If, for simplicity's sake, we assume that the magnitude of each of the several components of yield is the same and express it as Y then (I) becomes:

$$dY/dN = k(Ym\text{-}Y)^n \qquad \text{(II)}$$

where k is a constant. In our experiments where the dominant yield-limiting factor was damage from *M. arenaria* larvae (11), we can assume that the number of yield components is limited. In the simplest model, n=1, so that (II) becomes:

$$dY/dN = k(Ym\text{-}Y)$$

or

$$dY/(Ym\text{-}Y) = kdN \qquad \text{(III)}$$

Since $\int dY/(Ym\text{-}Y) = -\ln[Ym\text{-}Y] + C'$

and $k \int dN = kN + C''$

C′ and C′′ being constant, then

$$Y = Ym - e^{C-kN} \qquad \text{(IV)}$$

where $C = C'' - C'$.

The effects of aldicarb applications on yield considered independently of the effects of 1,3-D on the variable could be described adequately by equation IV (Fig. 1). Ym was higher for 1983 than for 1984. This was not unexpected since larval populations in the 1984 experiment were more than double the size of those in the preceeding year's experiment. There is an inverse relationship between plant yield and the number of larvae of *M. arenaria* in soil near harvest time (11). Equation IV also described the effect of 1,3-D applications on yield for 1983 but not for 1984 (Fig. 3). Although the lack of conformance of the 1984 data with the model may be thought anomalous it was not unexpected. The relation expressed in (II) implies that all dosages of the nematicide will be effective in increasing yield to some degree. In 1984, 1,3-D dosages were ineffective in increasing yield. It is possible that applications of 1,3-D in 1984, for reasons unknown to us, may have caused much higher phytotoxicity than in 1983, resulting in no significant yield responses.

Reductions in larval populations (L) in soil through applications of aldicarb could be described by the hyperbola

$$L = A + B/N \qquad \text{(V)}$$

where A and B are constants and N represents nematicide rate (Fig. 1). Equation V indicates that there is a limit A towards which the nematode population can be reduced by increasing nematicide rates. For aldicarb the value of A was 3.7 times higher in 1984 than in 1983, a reflection of the lower larval populations in the 1983 experiment.

The effect of 1,3-D on larval populations in 1983 could also be described by (V), however, this was not the case for the 1984 experiment (Fig. 3). In 1984 the effect of 1,3-D on *M. arenaria* larvae was linear. It is conceivable that the observed linear response may represent only a "branch" of a hyperbola since larval numbers in 1984 were much higher; the rate at which larval populations were declining in response to in-

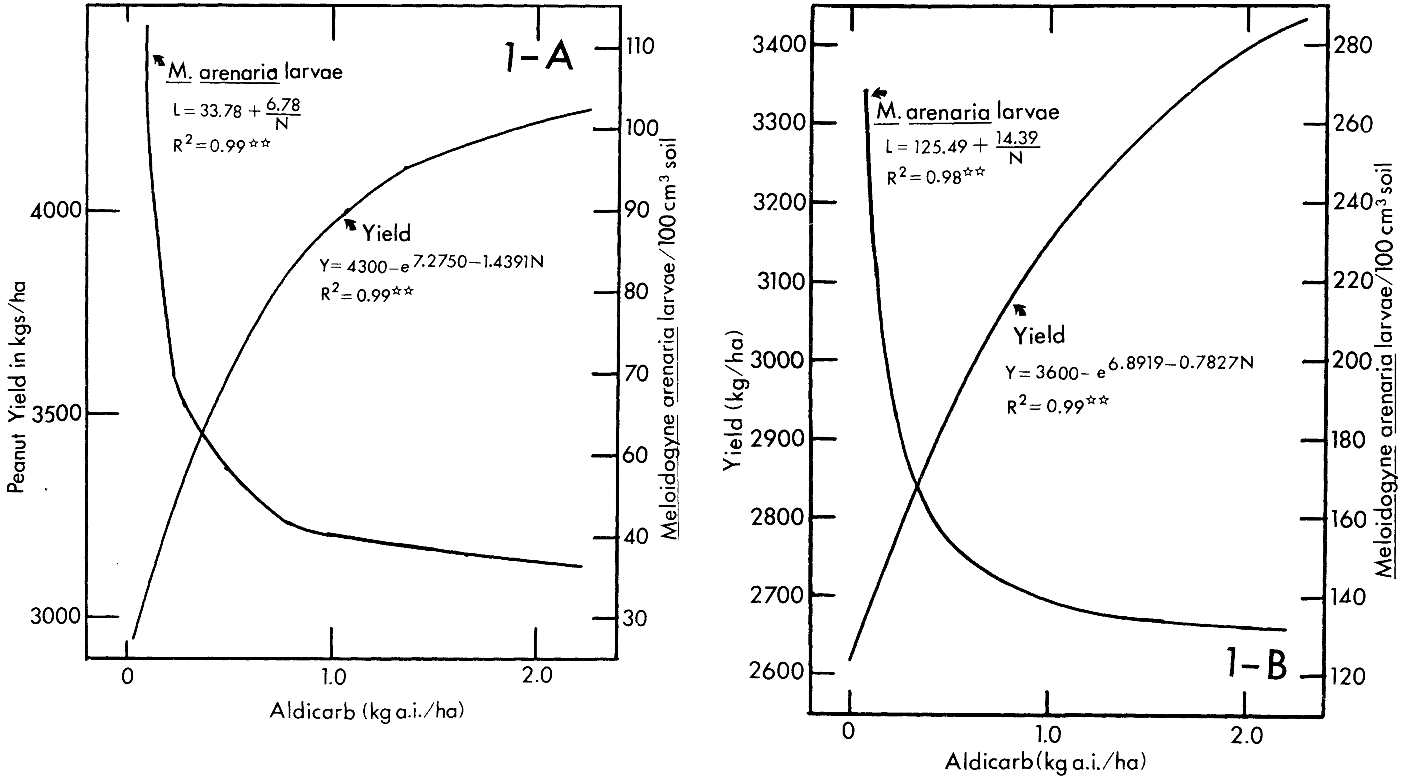

Fig. 1. Relation between aldicarb rate (N) and yield (Y) or number ot larvae (L) of *Meloidogyne arenaria* in soil in field experiments conducted in 1983 (A) and 1984 (B).

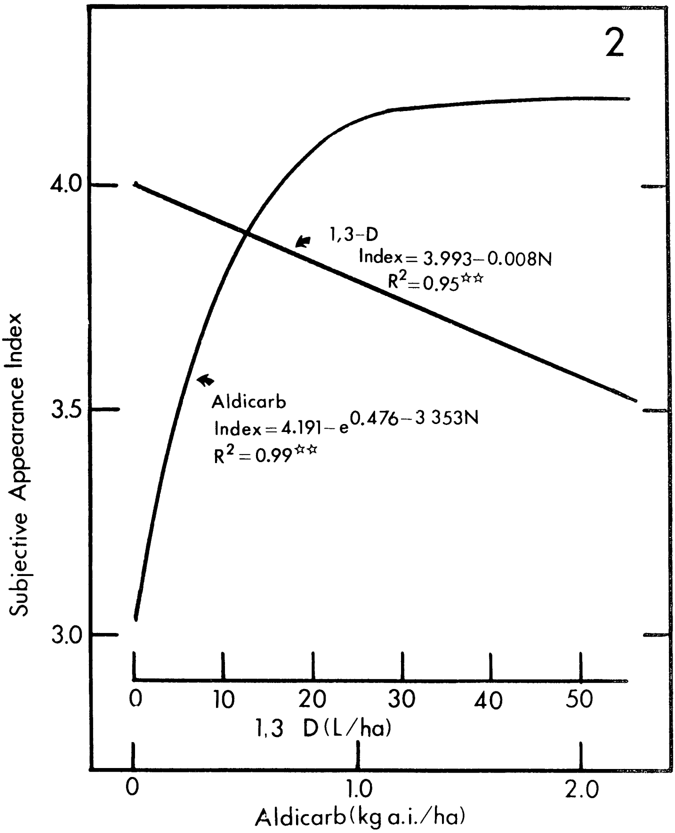

Fig. 2. Relation between nematicide rate (N) and subjective appearance index values for peanut plants in a 1983 experiment with 1,3-D and aldicarb (Index values were on a scale of 1 to 5 where 1 represented the worst looking plants and 5 plants in excellent condition).

creasing 1,3-D dosages remained fairly constant, larval values never approaching a lower asymptote.

The effects of aldicarb in 1983 on subjective appearance index values were similar to the effects of the nematicide on yield. Indeed, an equation like (IV) adequately described the relation between index values and aldicarb dosages (Fig. 2).

Results from the study indicate that it is possible to increase yields and reduce larval populations with at-plant applications of 1,3-D. This agreed with results obtained on soybeans (5,8); however, there are limitations on effective rates. The most consistent response was obtained with the 34.4 L/ha rate. The results also suggest that although feasible

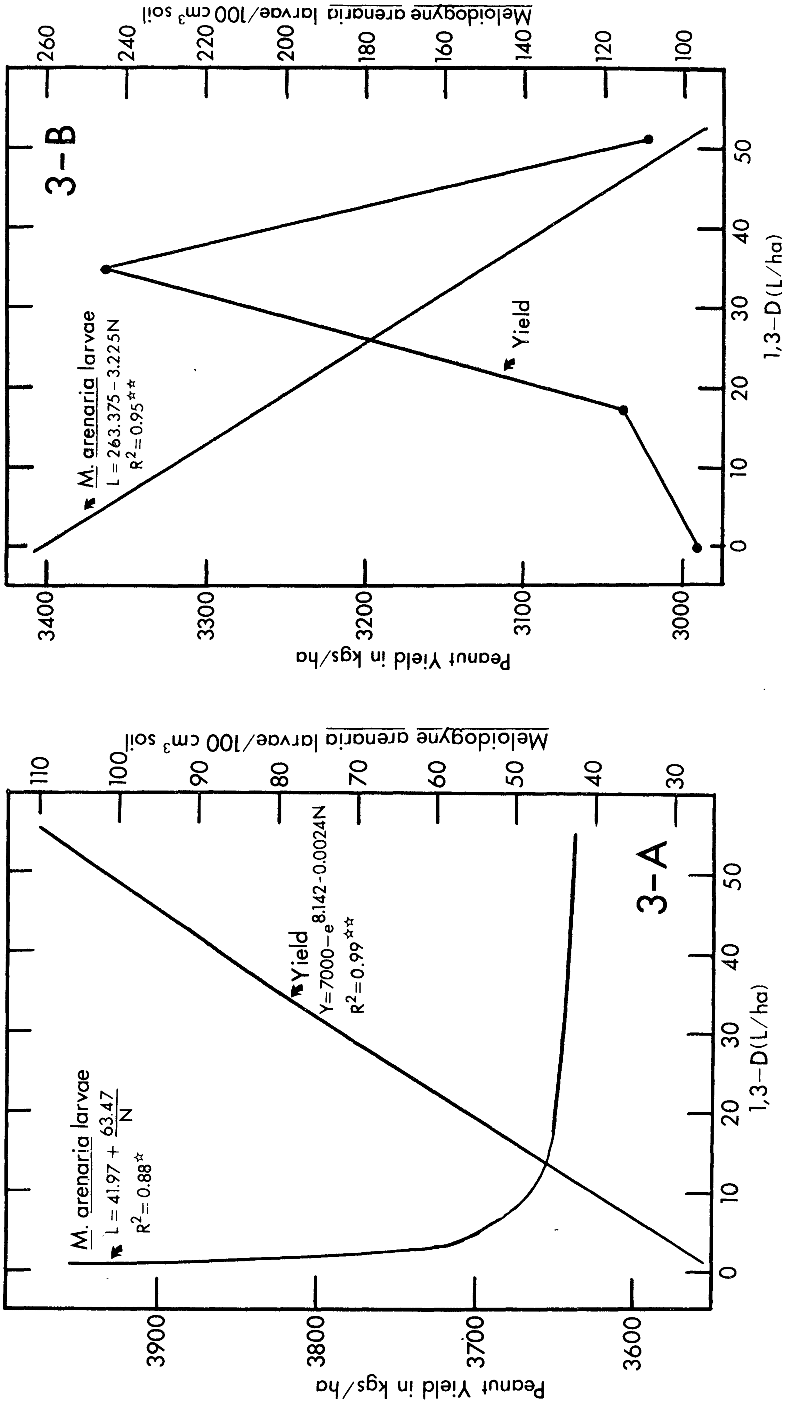

Fig. 3. Relation between 1,3-D dosages (N) and yield (Y) or number of larvae (L) of *Meloidogyne arenaria* in soil in field experiments conducted in 1983 (A) and 1984 (B).

from the point of view of yield response, at-plant applications of 1,3-D were always somewhat phytotoxic. Thus, in 1983 the subjective appearance index values declined significantly when 1,3-D was used in combination with aldicarb when compared with the values obtained with aldicarb alone; in 1984, 1,3-D applications did not result in increased yield although they reduced larval populations.

Results also indicate that it is possible to equal or surpass the performance of EDB in increasing yields and reducing larval populations when combinations of 1,3-D and aldicarb are used in peanut fields infested with *M. arenaria.* It may be possible that improvements in the method of application of 1,3-D will eliminate its phytotoxic effect and result in greater and more consistent yield responses from at-plant treatments with the fumigant.

LITERATURE CITED

1. GAZAWAY, W.S., F.A. GRAY, and R. ADAMS. 1977. Alabama Plant Disease and Nematicide Chemical Control Handbook. Ala. Coop. Ext. Serv. Cir. ANR-105, Auburn, Alabama. 94 pp.
2. INGRAM, E.G., and R. RODRIGUEZ-KABANA. 1980. Nematodes parasitic of peanuts in Alabama and evaluation of methods for detection and study of population dynamics. Nematropica 10:21-30.
3. MINTON, N.A., and R.O. HAMMONS. 1975. Evaluation of peanut for resistance to the peanut root knot nematode, *Meloidogyne arenaria.* Plant Dis. Reptr. 59:944-945.
4. PORTER, D.M., D.H., SMITH, and R. RODRIGUEZ-KABANA (eds.). 1984. Compendium of Peanut Diseases. Amer. Soc. Phytopathology, St. Paul, Minnesota. 73 pp.
5. RODRIGUEZ-KABANA, R., H.W. PENICK, P.S. KING, F.A. GRAY, E.L. CARDEN, N.R. MCDANIEL, and F.B. SELMAN. 1979. Efficacy of planting time application of 1,3 dichloropropene for control of nematodes on soybeans. Nematropica 9:66-71.
6. RODRIGUEZ-KABANA, R., and M.H. POPE. 1981. A simple method for the extraction of nematodes from soil. Nematropica 11:175-186.
7. RODRIGUEZ-KABANA, R., R.A. SHELBY, P.S. KING, and M.H. POPE. 1982. Comparison of methods of application with two systemic nematicides for control of root-knot nematodes in peanut and soybean. Nematropica 12:97-109.
8. RODRIGUEZ-KABANA, R., R.A. SHELBY, P.S. KING, and M.H. POPE. 1982. Combination of anhydrous ammonia and 1,3,-dichloropropenes for control of root-knot nematodes in soybean, Nematropica 12:61-69.

9. RODRIGUEZ-KABANA, R., and J.T. TOUCHTON. 1984. Corn and sorghum as rotational crops for management of *Meloidogyne arenaria* in peanut. Nematropica 14:26-36.
10. RODRIGUEZ-KABANA, R., R.A. SHELBY, P.S. KING, and M.H. POPE. 1982. Application time and effectiveness of four systemic nematicides against *Meloidogyne arenaria* on Florunner peanut. Nematropica 12:85-96.
11. RODRIGUEZ-KABANA, R., J.C. WILLIAMS, and R.A. SHELBY. 1982. Assessment of peanut yield losses caused by *Meloidogyne arenaria*. Nematropica 12:279-288.
12. STEEL, R.G.D., and J.H.TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York. 481 pp.

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