EVALUATION OF NEMATICIDES FOR CONTROL OF ROOT-KNOT AND CYST NEMATODES ON A TOLERANT SOYBEAN CULTIVAR

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ABSTRACT

Rodriguez-Kabana, R., D. G. Robertson, P. S. King, and C. F. Weaver. 1987. Evaluation of nematicides for control of root-knot and cyst nematodes on a tolerant soybean cultivar. Nematropica 17:61-70.

A 3-year study was conducted with 'Kirby' soybean (*Glycine max*) in a field in south Alabama to assess the efficacy of at-plant applications of aldicarb (Temik® 15G), phenamiphos (Nemacur® 15G), 1,3-D (Telone® II) and EDB (Soilbrom 90®) for control of *Heterodera glycines, Meloidogyne arenaria,* and *M. incognita.* Aldicarb and phenamiphos were applied in a 12-cm-wide band at rates of 0, 1.1, 2.2, and 3.3 kg a.i./ha. Fumigants were applied in the row to a depth of 40 cm using 2 injectors per row; 1,3-D was applied at rates of 18.7 and 37.4 L/ha and EDB at 16.8 L/ha. EDB was used only in the first 2 years of the study. All nematicide treatments increased yields. Yield responses to applications of aldicarb and phenamiphos followed a first order kinetic model defined by $Y=K-e^{(A+Bx)}$, where Y represents yield, x nematicide rate, and A, B, and K are constants. The 2 lowest rates of aldicarb or phenamiphos would result in profitable yield responses but the 3.3-kg rate would not be economical. The only profitable application of 1,3-D was at the 37.4 L rate. Yield responses to EDB were either the highest (1984) or among the highest (1985) of all treatments in the study. Nematicide treatments had no effect on juvenile populations of *H. glycines* in soil. *Meloidogyne* juvenile populations in soil were reduced by the treatments in 2 (1984 & 1986) of the 3 years of the study.

Additional key words: pest management, carbamate, phosphorothioates, organophosphates, legumes, plant breeding, quantitative nematology, crop losses.

RESUMEN

Rodríguez-Kábana, R., D. G. Robertson, P. S. King y C. F. Weaver. 1987. Evaluación de nematicidas para combatir los nematodos agalladores y del quiste en un cultivar tolerante de soya. Nematrópica 17:61-70.

Se efectuó un estudio de campo por tres años (1984-1986) con soya (*Glycine max*) 'Kirby' con el objetivo de evaluar la eficacia de tratamientos de siembra con aldicarb (Temik® 15G), fenamifos (Nemacur® 15G), 1,3-D (Telone® II) y EDB para combatir *Meloidogyne arenaria, M. incognita* y *Heterodera glycines.* Los tratamientos con aldicarb y fenamifos se efecturaron en una franja de 12-cm de ancho y en dosis de 0, 1.1, 2.2, y 3.3 kg i.a./ha. Los fumigantes se inyectaron en el suelo a una profundidad de 40 cm; el 1,3-D se empleó en dosis de 18.7 y 37.4 L/ha y el EDB con una de 18.7 L/ha. El EDB se utilizó, sólo en los dos primeros años del estudio. Todos los tratamientos con nematicidas resultaron en aumentos de rendimientos. Los aumentos en la producción debidos al empleo de aldicarb o del fenamifos quedaron relacionados con las dosis por la función $Y=K\text{-}e^{(A+Bx)}$ que es el modelo de la ecuación de cinética de primer orden, en la cual Y representa los rendimientos de soya, x las dosis del nematicida, y A, B, y K son constantes. Los resultados señalaron que el empleo del aldicarb o del fenamifos sólo es económico con las dosis de 1.1 y de 2.2 kg/ha pero que no lo es con la de 3.3 kg. La única dosis útil de 1,3-D fué la de 37.4 L. Ninguno de los tratamientos nematicidas afectó las poblaciones larvales de *H. glycines* en el suelo aunque no fué asi para con las de *Meloidogyne* las que fueron reducidas por los tratamientos en 2 (1984 y 1986) de los 3 años del estudio.

Palabras claves adicionales: manejo de plagas, carbamatos, fosforotioatos, fosfatos orgánicos, legumbres, fitomejoramiento, nematología cuantitativa, pérdidas de rendimientos.

INTRODUCTION

The soybean (*Glycine max* Merr.) is a good host for a number of nematode species (3,14). In the southern United States, damage from nematodes is one of the limiting factors in the production of this legume (2,3). Yield losses in fields with high infestations of root-knot (*Meloidogyne* spp.) and cyst (*Heterodera glycines* Ichinohe) nematodes can be so severe (12,13) that soybean production is not possible. The management of nematode problems in soybean in the southeastern U.S.A. has depended primarily on the development of cultivars tolerant (or resistant) to the economically important *Meloidogyne* spp. and to *H. glycines*. Presently there are commercial cultivars available with reasonable levels of tolerance to *M. incognita* (Kofoid & White) Chitwood and resistance to several races of *H. glycines* but there are few cultivars tolerant to *M. arenaria* Neal (Chitwood) (3). It has been shown, however, that yields of even the most tolerant or resistant cultivars can be substantially improved by the use of nematicides (4,6). This is especially so in fields infested with combinations of root-knot and cyst nematodes (9,16). In the past the use of dibromochloropropane (DBCP) and ethylene dibromide (EDB) provided an inexpensive and highly efficacious means of controlling nematodes in the crop (3). These fumigants are no longer available for use by farmers and consequently there is great need to develop adequate substitute treatments. Nematicides currently available for use in soybean include the systemics aldicarb and phenamiphos, and fumigants containing 1,3-dichloropropenes (1,3-D); however, the performance of these nematicides when used with nematode-susceptible soybean cultivars has been unsatisfactory (authors' unpublished data). The relatively recent release of soybean cultivars with high levels of tolerance to *M. incognita* and resistance to *H. glycines* opened the possibility that available nematicides may perform well with these cultivars. This paper presents results of a long-term study on the performance of nematicides with one of the new cultivars tolerant to *M. incognita* and resistant to three races of *H. glycines*.

MATERIALS AND METHODS

A three-year study was conducted in a field near Elberta, Baldwin County, Alabama, to assess the efficacy of systemic and fumigant nematicides for control of soybean nematodes. The field was infested with *M. arenaria, M. incognita,* and race 3 of *H. glycines.* In 1984, *M. incognita* represented over 90% of females isolated from soybean roots, but in 1986, 64% of the females were *M. incognita* and 36% were *M. arenaria.* The field had been in continuous soybean production for the preceeding 6 years with wheat (*Triticum aestivum* L.) or annual ryegrass (*Lolium* spp.) planted as winter cover crop. 'Kirby' soybean was chosen for the study since it was tolerant to *M. incognita* and resistant to race 3 of *H. glycines;* however, this cultivar is susceptible to *M. arenaria.* All nematicides were applied at planting time. The systemic nematicides aldicarb (Temik® 15G) and phenamiphos (Nemacur® 15G) were lightly incorporated 3-5 cm deep in a 12-cm band at rates of 0, 1.1, 2.2, and 3.3 kg a.i./ha, equivalent to broadcast rates of 0, 5.8, 11.7, and 17.6 kg a.i./ha, respectively. Fumigants were 1,3-D (Telone® II) and EDB (Soilbrom 90®); these nematicides were injected into the soil to a depth of 40 cm using 2 injectors per row set 25 cm apart with the seed furrow between them. EDB was applied at 16.8 L/ha and 1,3-D at 18.7 and 37.4 L/ha. The EDB treatment was used only in the first 2 years of the study (1984 and 1985). Each year every treatment was represented by 8 replications (plots) within a randomized complete block design. A plot was 2 rows, each 0.8 m wide and 6 m long. Cultural practices and control of weeds, insects, and foliar diseases were as recommended for the area (1). Yield data were obtained at maturity of the crop by harvesting the entire plot areas.

Soil samples for nematode analysis were collected from all plots 4-6 wk before harvest to coincide with the period of maximal population development of *M. incognita* in soil (10). A sample consisted of 16-20 cores/plot obtained with a standard 2.5-cm-diam probe to a depth of 20-25 cm. The cores were obtained from the 2 rows at 0.4-0.6 m spacings by inserting the probe into the root zone. The cores from each plot were composited and a 100-cm^3 subsample was used to determine nematode numbers using the "salad bowl" incubation method (8).

All data were analyzed following standard procedures for analysis of variance (15). Regression analysis and curve fitting by the least squares method were also following standard procedures (5,15). Fisher's least significant differences (L.S.D.) were calculated and are included in the table of results. Unless otherwise stated all differences referred to in the text were significant at the 5% or lower level of probability.

Table 1. Effect of at-plant nematicide treatments on yield of 'Kirby' soybean and on juvenile populations in soil of *Meloidogyne arenaria, M. incognita,* and *Heterodera glycines* in a 3-year study in a field near Elberta, Alabama.

		1984			1985			1986		
		Juveniles/100 cm³ soil			Juveniles/100 cm³ soil			Juveniles/100 cm³ soil		
	Rate[y] (L or kg a.i./ha)	*M. arenaria* + *M. incognita*	*H. glycines*	Yield (kg/ha)	*M. arenaria* + *M. incognita*	*H. glycines*	Yield (kg/ha)	*M. arenaria* + *M. incognita*	*H. glycines*	Yield (kg/ha)
Control		533	54	1599	114	92	984	371	76	1030
Aldicarb	1.1 kg	223	47	1846	120	96	1088	237	93	1226
Aldicarb	2.2 kg	252	31	2146	46	107	1144	120	88	1556
Aldicarb	3.3 kg	172	67	2283	122	58	1190	118	65	1587
Phenamiphos	1.1 kg	281	78	1734	59	106	1037	157	72	1281
Phenamiphos	2.2 kg	246	33	1831	104	67	1149	195	97	1353
Phenamiphos	3.3 kg	198	24	1994	149	66	1195	217	44	1368
1,3-D'	18.7 L	471	70	1724	139	73	1073	192	64	1159
1,3-D	37.4 L	235	46	2136	192	58	1220	211	46	1124
EDB-90	16.8 L	71	36	2568	29	90	1190	—	—	—
	LSD (P=0.05):	226	N.S.[z]	191	81	N.S.	187	157	N.S.	301

[y] Aldicarb (Temik® 15G) and phenamiphos (Nemacur® 15G) applied in a 13 cm band and incorporated 5 cm deep; 1,3-D (Telone® II) and EDB-90 injected 40 cm deep using 2 injectors/row.

[z] N.S. = not significant; dashes (—) indicate treatment not used.

RESULTS AND DISCUSSION

Nematicide treatments had no effect on juvenile populations of *H. glycines* in any of the 3 years of the study; however, several treatments reduced *Meloidogyne* juvenile populations (Table 1). The interaction of year x treatment on *Meloidogyne* populations was not significant. Overall numbers of *Meloidogyne* juveniles were higher in 1984 and 1986 than in 1985. The relationship of application rate in kg a.i./ha (x) and the 3-year averages for numbers of *Meloidogyne* juveniles in 100 cm^3 soil (Ji) was significant for aldicarb ($R^2=0.98^{**}$) and for phenamiphos ($R^2=0.97^{**}$). The function describing the relation for aldicarb (Fig. 1A) was:

$$Ji = 198.8 - 80.7\ \ln(x) \qquad \text{(I)}$$

The equation indicates that the greatest decline in juvenile numbers occurred in response to the two lowest rates of aldicarb.

The hyperbola (Fig. 1B)

$$Ji = 169.63 + 16.92/x \qquad \text{(II)}$$

defined the relation between phenamiphos rates and the 3-year averages for numbers of *Meloidogyne* juveniles in 100 cm^3 soil. Equations I and II indicated that for both aldicarb and phenamiphos, the largest portion of *Meloidogyne* control was obtained with the use of the 2.2-kg rate.

Soybean yields were lowest in 1985 and highest in 1984; however, there was a general pattern of response to increasing rates of nematicide each year without a significant year x treatment interaction. The effect of aldicarb treatments on yield (Y) was described ($R^2=0.98^{**}$) by the function (Fig. 2A):

$$Y = 2000 - e^{6.602-0.595x} \qquad \text{(III)}$$

Equation III is based on 3-year averages and it indicates that the rate of increase in yield in relation to increasing nematicide rate or dY/dx is dependent on the difference between a theoretical maximal yield K and the yield (Y) corresponding to any nematicide rate x, or

$$dY/dx = K(K-Y) \qquad \text{(IV)}$$

where K is a constant. In equation III where K=2000 kg/ha, dY/dx decreases continuously as yield (Y) increases and K is approached, in response to increasing nematicide rates. We have proposed this "first order kinetic model" before to describe peanut yield responses to nematicide applications (11). In the present case, equations III and IV clearly indicate that the greatest yield responses in terms of net return would be obtained with the two lowest rates of aldicarb. The cost of the 1.1-kg treatment of aldicarb is approximately U.S. $41.83 at current prices in Alabama. Equation III indicates that at prevailing soybean prices ($184/

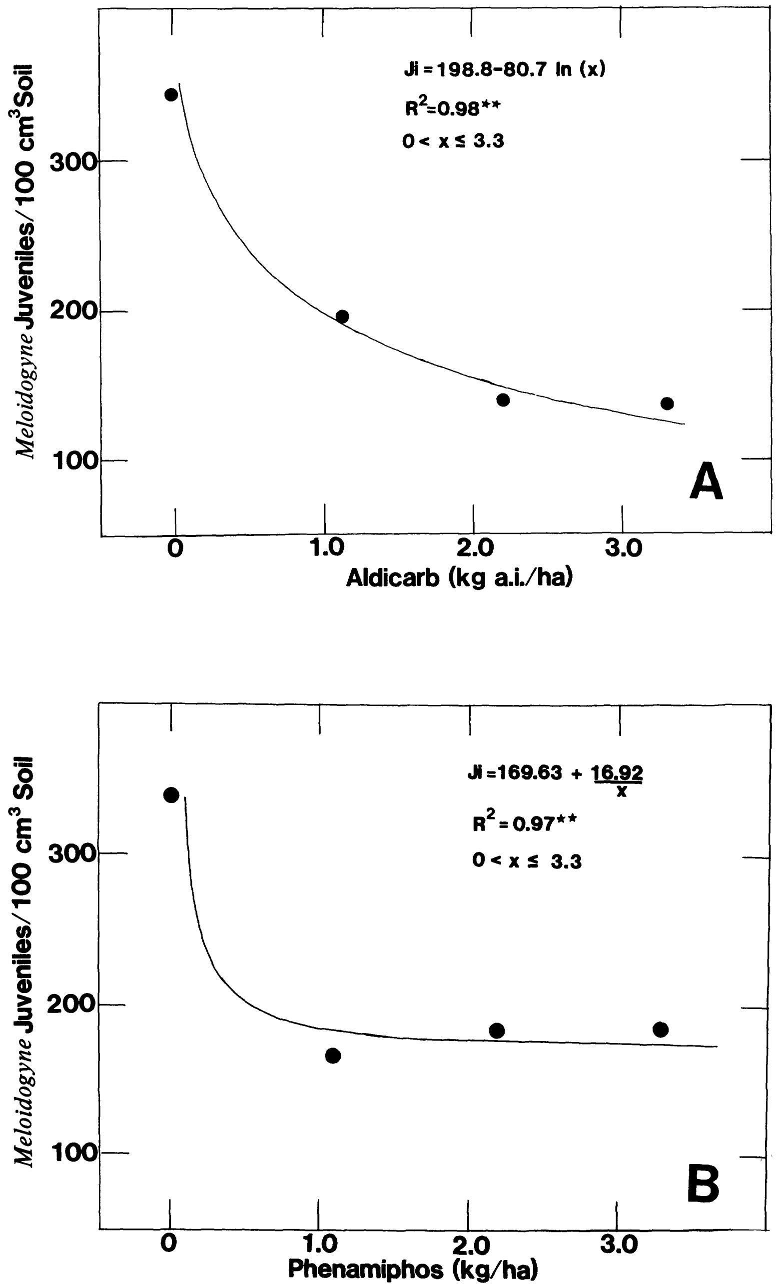

Fig. 1. Relation between average numbers of *Meloidogyne* juveniles and rates of aldicarb (A) or phenaimphos (B) in a 3-year field study with 'Kirby' soybean.

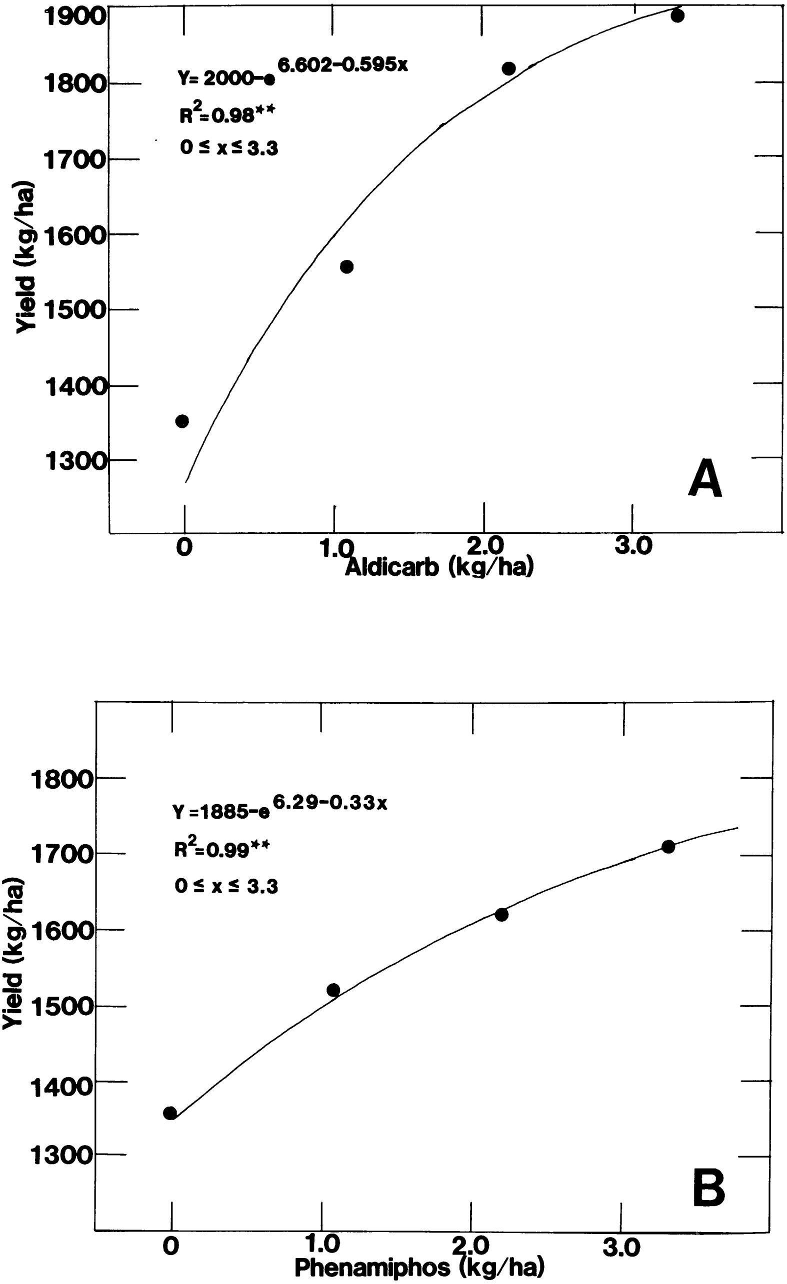

Fig. 2. Average yield response of 'Kirby' soybeans to applications of aldicarb (A) or phenamiphos (B) in a 3-year study in a field infested with *M. arenaria, M. incognita,* and *H. glycines.*

mt), the two lowest rates of aldicarb were profitable, but that the 3.3-kg (or any higher rate) is not economical.

The first order kinetic model was also appropriate ($R^2=0.98^{**}$) to describe the relation between average yields and phenamiphos rates; the equation for this nematicide (Fig. 2B) was:

$$Yp = 1885\text{-}e^{6.29-0.33x} \qquad (V)$$

Economic analysis of the yield responses revealed that, as with aldicarb, the two lowest rates of phenamiphos were profitable at prevailing prices for the nematicide ($28-30/kg a.i.).

Our results indicate that aldicarb is more effective than phenamiphos for increasing yields within the range of rates used in our study. We have found a similar relation between aldicarb and phenamiphos for control of *M. arenaria* in peanut (7).

Average yields for the 3 years were correlated ($R^2=0.78^*$) with corresponding average numbers of *Meloidogyne* juveniles in the soil by the function (Fig. 3):

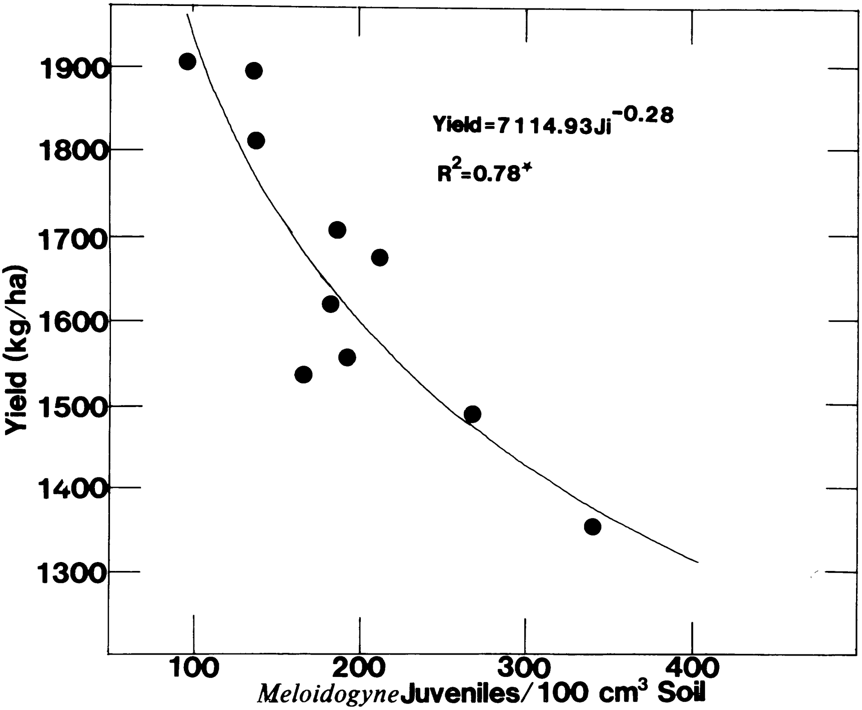

Fig. 3. Relation between 'Kirby' soybean yields and *Meloidogyne* juvenile populations in a 3-year study in a field infested with *M. arenaria*, *M. incognita*, and *H. glycines*.

$$Y = 7114.93Ji^{-0.28} \qquad \text{(VI)}$$

Although this function described the relation for all treatments, there were differences according to nematicides. Thus, while the relation between yield and juvenile numbers for aldicarb was significant ($R^2 = 0.98^{**}$) and according to the equation:

$$Y = Ji/(0.0003Ji-0.0466) \qquad \text{(VII)}$$

we were not able to develop a relevant model to describe the relation between the variables with the phenamiphos data.

Yield data for the 1,3-D treatments showed that the 37.4-L rate was the only effective rate of the two rates of this chemical used in the study. The 37.4-L rate of 1,3-D resulted in yield responses equivalent to those obtained with the highest rate of phenamiphos; current prices for 1,3-D ($0.8-0.9/L) permit the use of this treatment profitably. Applications of EDB resulted in the highest yield response to any treatment in 1984 and in one of the highest yields in 1985. EDB was available before its banning at prices that would have made it the most profitable treatment of all those in the study.

The 'Kirby' soybean is resistant to race 3 of the soybean cyst nematode. *H. glycines* juvenile populations in soil were relatively low, probably reflecting the high degree of resistance to race 3 of this nematode. No relation could be established between yield and juvenile populations of *H. glycines* in soil. We interpret the yield response obtained with the nematicide treatments as resulting from control of the root-knot nematodes (Fig. 3). It was not possible to separate juvenile populations of *M. arenaria* from those of *M. incognita.*

CONCLUSIONS

Our results demonstrated that treatments with aldicarb or phenamiphos at rates of 1.1 or 2.2 kg a.i./ha can result in profitable yield responses when used with a soybean cultivar like 'Kirby' in fields infested with *H. glycines* and *Meloidogyne* spp. In such fields the use of 1,3-D at 18.7 L/ha is not effective, but applications of the fumigant at 37.4 L/ha can result in profitable yield increases.

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