COMPARISON OF METHODS OF APPLICATION WITH TWO SYSTEMIC NEMATICIDES FOR CONTROL OF ROOT-KNOT NEMATODES IN PEANUT AND SOYBEAN

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Accepted:
2.IV.1982
Aceptado:

ABSTRACT

Rodríguez-Kábana, 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.

Aldicarb (Temik® 15G) and phenamiphos (Nemacur® 15G) were applied at planting time in banded, in-furrow, and combination banded + in-furrow treatments to control *Meloidogyne arenaria* (Neal) Chitwood in peanut (*Arachis hypogaea* L.) and *M. incognita* (Kofoid & White) Chitwood in soybean (*Glycine Max* Merr.). The banded treatments were applied at rates of 1.1, 2.2, 3.4, and 4.4 kg a.i./ha and the in-furrow treatments at rates of 1.1 and 2.2 kg a.i./ha. Combination treatments were at rates of 1.1 and 2.2 kg a.i./ha for both the banded and the in-furrow components. Results indicated that simple band treatments provided equal or better nematode control and yield increases than the simple in-furrow treatments in both peanut and soybean. The combination treatments did not result in any significant advantage over the simple banded treatments at equivalent rates for nematode control or yield response.
Additional key words: chemical control, methods of application, techniques, pest management, non-fumigant nematicides, contact nematicides, carbamates, phophorothioates.

RESUMEN

Rodríguez-Kábana, R., R.A. Shelby, P.S. King, and M.H. Pope. 1982. Estudio comparativo de métodos de aplicación con dos nematicidas sistémicos para combatir nematodos noduladores en maní y soya. Nematropica 12: 97-109.

Se aplicaron los nematicidas aldicarb (Temik® 15G) y fenamifos (Nemacur® 15G) durante la siembra en la sementera (in-furrow), en franjas, y también en tratamientos que combinaron aplicaciones en franja y en la sementera, para combatir *Meloidogyne arenaria* (Neal) Chitwood en maní (*Arachis hypogaea* L.) y *M. incognita* (Kofoid & White) Chitwood en soya (*Glycine Max* Merr.). Los tratamientos en franja fueron con dosis de 1.1, 2.2, 3.4, y 4.4 kg i.a./ha y los en semetera con 1.1 y 2.2 kg i.a./ha. Tratamientos combinados se efectuaron con dosis de 1.1 y 2.2 kg i.a./ha para el componente en franja asi como para el de en sementara. Los datos obtenidos con los dos cultivos señalaron que los tratamientos

simples en franja resultaron en igual o mejor grado de combate de los nematodos y aumentos en rendimientos que los resultantes de los tratamientos simples en sementera. También, no se observaron ventajas significativas con el uso de tratamientos combinados cuando los resultados que les correspondian se compararon con los obtenidos con tratamientos simples en franjas a dosis equivalentes.
Palabras claves adicionales: combate químico, métodos de aplicación, técnicas, manejo de plagas, nematicidas no-fumigantes, nematicidas de contacto, carbamatos, fosforotioatos.

INTRODUCTION

The damage caused by root-knot nematodes (*Meloidogyne* Goeldi) peanut (*Arachis hypogaea* L.) and soybean [*Glycine Max* (L.) Merr.] is one of the limiting factors in production of these crops in the southeastern U.S.A. (6,12,13,25,26). Because of the lack of resistant cultivars (10) control of these nematodes in peanut is presently based on the use of nematicides (13,19,22). In contrast, a number of soybean cultivars with resistance to *Meloidogyne* spp are available (4,6). However, resistant or tolerant soybean cultivars can sustain significant yield losses in fields with severe infestations of the nematodes (6,12,18). For some species of the root-knot nematode, e.g. *M. arenaria* (Neal) Chitwood, prevalent in the southeastern U.S.A., the level of resistance available in soybeans is inadequate (4,6). Another difficulty in controlling nematodes with the sole use of resistant cultivars is that no commercial cultivars are presently available with combined resistance to all the common species of *Meloidogyne* and other plant parasitic nematodes prevalent in fields of the southeastern U.S.A. (6,23,24). The complexity of nematode species that occur in typical soybean fields in Alabama dictates a control strategy that combines the use of resistant varieties with use of effective nematicides (6).

The systemic nematicides aldicarb and phenamiphos are among the most efficacious of those used in peanut and soybean in Alabama (3,13). However, proper use of these compounds requires a good understanding of their properties and behavior under typical field conditions. Previous work has shown that the relative efficacy of these compounds against root-knot nematodes is affected by the method of application (11,17,20), the degree of incorporation into soil (16), and application time (9,22). Our results indicate that these compounds are most effective against root-knot nematodes when they are applied at or near planting time and in banded rather than in-furrow applications. However, we believed that treatments combining the simultaneous application of banded and in-furrow dosages of these nematicides may be superior to treatments in which the nematicides were applied in simple bands. This paper presents results of a study conducted in 1981 to evaluate the relative efficacy of combination band + in-furrow treatments for control of root-knot nematodes in peanut and soybean.

MATERIALS AND METHODS

The effect of combined in-furrow and band treatments of aldicarb and phenamiphos on populations of species of *Meloidogyne* Goeldi was studied in 1981 with peanut and soybean. Peanut experiments with the Florunner cultivar were established at the Wiregrass Substation near Headland, Alabama, in a field infested with *Meloidogyne arenaria* (Neal) Chitwood. The field was irrigated and had been with peanut and with hairy vetch (*Vicia villosa* Roth) as the winter crop for the preceeding six years. Experiments with Ransom soybean were in a field infested with *M. incognita* (Kofoid & White) Chitwood near Elberta, Baldwin county, Alabama. The field was not irrigated and had been in soybean with winter fallow during the preceeding two years.

One experiment with peanut and one with soybean were established for each nematicide. In each experiment the nematicide was applied at planting time at rates of 1.1 and 2.2 kg a.i./ha in-furrow and at 1.1, 2.2, 3.3, and 4.4 kg. a.i./ha in band applications. Band widths were 30 cm for peanut experiments and 18 cm for soybean. Each experiment also contained combination in-furrow + band treatments in which in-furrow rates of 1.1 and 2.2 kg a.i./ha were applied simultaneously with band applications of the nematicide at the same rates in all possible combinations. All experiments had a no treatment control and two treatments with EDB 90 (Soilbrom® 90) applied at planting at rates of 9.35 and 18.70 l/ha. EDB 90 was applied to a depth of 20 cm using two injectors per row each 10 cm on each side of the seed furrow.

Nematicides applied in band applications were incorporated lightly (3-6 cm) into the soil with spring activated tines positioned immediately behind the applicator.

Plots in each experiment consisted of two 91-cm rows either ten (peanut) or six (soybean) m long. Each treatment in every experiment was represented by eight plots arranged in a randomized complete block design.

Cultural practices and control of weeds, foliar diseases and insects in the experiments were according to recommendations for the areas (3). In the peanut experiments supplemental irrigation was used as needed to maintain good growth of the crop. The soybean experiments received adequate rainfall through the season for development of the crop.

Soil samples for nematode analysis were collected four (peanut) or eight (soybean) weeks before harvest to coincide with the periods of maximal larval population development of the nematodes in the crops (2,5). Samples were taken from the root zone to a depth of 20 cm using a 2.5 cm diam. soil probe. A total of 16-20 cores were collected from the center of each plot by sampling in zig-zag fashion along the entire length of the plots. Cores from each plot were composited and a 100 cm^3 subsample was used for analysis with the "bowl" technique (21).

In the peanut experiments the incidence of stem rot ("white mold") caused by *Sclerotium rolfsii* Sacc. was determined one week before harvest by counting the number of disease loci in each plot (14).

The relative appearance of plants in plots of peanut experiments was assessed using a subjective scale in which a value of one represented plots with unthrifty chlorotic plants with severely restricted plant coverage of the plot surface at midseason; a value of five was assigned to plots with plants showing excellent growth and plant coverage of the entire plot surface. In the soybean experiments a similar evaluation was conducted 45 days after planting when a value of one was ascribed to plots with severely stunted, chlorotic plants and a value of five to plots with plants showing excellent growth and no stunting. In all experiments, yield was determined at maturity of the crops by harvesting the entire area of each plot.

All data were analysed following standard procedures for analysis of variance and differences among means were evaluated for significance according to a modified Duncan's multiple range test (27). Factorial analyses were also performed following standard procedures. Except where otherwise stated all differences referred to in the text were significant at the 5% or lower level of probability.

RESULTS

Peanuts. 1. Aldicarb experiment. Data from the aldicarb experiment are presented in Table 1. With one exception (EDB 90 at 9.35 l/ha) all nematicide treatments increased yields above the control. Among aldicarb treatments the lowest yield responses were obtained when the nematicide was applied as a simple in-furrow application at 1.1 kg a.i./ha. Factorial analysis of the yield data from aldicarb treatments indicated that the interaction between band and in-furrow applications was not significant; however, the analysis showed highly significant responses to aldicarb rates whether applied banded or in-furrow. Treatments in which aldicarb was applied solely in-furrow did not reduce larval populations of *M. arenaria*, but all other treatments in the experiment resulted in significant reductions in larval numbers compared with the number obtained for control plots. Factorial analysis of the data on larvae showed that the interaction between band and in-furrow applications was not significant. Also, the effect of in-furrow rates when considered independently of band treatments was not significant but the converse consideration showed that band treatments were highly significant. EDB 90 treatments failed to improve values for the subjective appearance index relative to values for control plots. The only aldicarb treatments that did not improve the subjective appearance of plots were those with rates of 2.2 and 4.4 kg a.i./ha applied in a band. Factorial analysis of the data on subjective appearance revealed an interaction between band and in-furrow applications so that no generalizations could be made regarding the method of application. Applications of aldicarb in a band at 1.1 kg a.i./ha combined with in-furrow treatments of 1.1 or 2.2 kg a.i./ha reduced the incidence of white mold. The combined band + in-furrow treatment of aldicarb at 2.2 kg a.i./ha

Table 1. Effect of EDB 90 (Soilbrom® 90) and combinations of in-furrow and band applications of aldicarb (Temik® 15G) on *Meloidogyne arenaria* and yield of Florunner peanut in a field experiment near Headland, Alabama.

	Rate (kg a.i./ha)		White Mold[x]	Subjective[z]	Larvae	Yield
	In-Furrow	Band (30 cm)	loci/plot	Appearance Index	per 100 cm^3 soil	(kg/ha)
Control			11.43 a[y]	3.56 d	228 a	3240 d
Aldicarb 15G	1.1	0.0	8.37 abc	4.25 abc	272 a	3719 bc
	2.2	0.0	6.87 abc	4.65 a	209 ab	4020 ab
	1.1	1.1	5.75 bc	4.12 bc	74 c	4245 a
	1.1	2.2	6.37 bc	4.37 ab	62 c	4220 a
	2.2	1.1	7.62 abc	4.62 a	41 c	4313 a
	2.2	2.2	4.75 c	4.25 abc	52 c	4258 a
	0.0	1.1	7.12 abc	4.25 abc	101 c	4044 a
	0.0	2.2	6.87 abc	4.00 bcd	63 c	4158 a
	0.0	3.3	8.37 abc	4.37 ab	46 c	4158 a
	0.0	4.4	9.12 abc	4.00 bcd	38 c	4028 ab
EDB 90 (l/ha)	9.35		9.62 ab	3.62 d	120 bc	3548 cd
EDB 90 (l/ha)	18.70		6.75 abc	3.87 cd	22 c	4218 a

[x]A locus represents an area of disease caused by *Sclerotium rolfsii* ≤ 30 cm of row length.

[y]Means within the same column followed by a common letter were not statistically different ($P = 0.05$).

[z]The subjective appearance index was based on a scale of 1-5 where a value of 1 represented plots with unthrifty chlorotic plants with severely restricted plant coverage of the plot surface at midseason; a value of 5 was ascribed to plots with plants showing excellent growth and plant coverage of the entire plot surface at midseason.

Table 2. Effect of at plant soil injections of EDB 90 (Soilbrom® 90) and combinations of in-furrow and band applications of phenamiphos (Nemacur® 15G) on *Meloidogyne arenaria* and yield of Florunner peanut in a field experiment near Headland, Alabama.

	Rate (kg a.i./ha) In-Furrow	Band (30 cm)	White Mold[x] loci/plot	Subjective[z] Appearance Index	Larvae per 100 cm^3 soil	Yield (kg/ha)
Control			10.87 abc[y]	3.62 cde	271 abc	3327 e
Phenamiphos	1.1	0.0	14.97 a	4.00 abc	440 a	3461 de
	2.2	0.0	9.12 bc	4.25 a	146 cd	3803 abc
	1.1	1.1	11.37 ab	3.37 e	213 bcd	3458 de
	1.1	2.2	8.25 bc	3.87 abcd	268 abc	3887 ab
	2.2	1.1	8.62 bc	3.50 de	387 ab	3748 abcd
	2.2	2.2	6.62 bc	4.12 ab	219 bcd	3963 a
	0.0	1.1	9.25 bc	3.37 e	194 bcd	3542 cde
	0.0	2.2	7.25 bc	3.50 de	165 cd	3634 bcde
	0.0	3.3	5.75 c	4.12 ab	147 cd	3843 abc
	0.0	4.4	9.25 bc	3.37 e	139 cd	3936 ab
EDB 90 (l/ha)	9.35		6.50 bc	3.75 bcde	119 cd	3995 a
EDB 90 (l/ha)	18.70		8.87 bc	3.62 cde	52 d	3955 a

[x]A locus represents an area of disease caused by *Sclerotium rolfsii* ≤ 30-cm of row length.

[y]Means within the same column followed by a common letter were not statistically different (P = 0.05).

[z]The subjective appearance index was based on a scale of 1-5 where a value of 1 represented plots with unthrifty chlorotic plants with severely restricted plant coverage of the plot surface at midseason; a value of 5 was ascribed to plots with plants showing excellent growth and plant coverage of the entire plot surface at midseason.

also reduced incidence of white mold. The interaction of in-furrow and band applications for the white mold data was not significant; however, when the effects of banded applications were considered independently of those from in-furrow applications a reduction in white mold was detected but the same was not true for the reverse consideration.

2. *Phenamiphos Experiment.* Results from the phenamiphos experiment are presented in Table 2. Applications of EDB 90 and of phenamiphos in simple band applications at rates above 2.2 kg a.i./ha increased yields. Phenamiphos applied in-furrow at 1.1 kg a.i./ha either alone or combined with an equal rate in a band did not result in yield increases; all other phenamiphos treatments improved yield. The interaction between application methods for phenamiphos treatments was not significant. When yield data for in-furrow applications were considered independently of the effect of banding treatments an increase in yield was evidenced; increases in yield also were evident when data from banding applications were considered independently of the effect of in-furrow components. EDB 90 at 18.7 l/ha was the only treatment that reduced larval numbers below those found in control plots. Factorial analysis of the phenamiphos data for larvae revealed no effects from banding or in-furrow applications and no interaction between the two methods of application. The only nematicide treatments that improved values for the subjective appearance index were those with phenamiphos applied in-furrow alone at 2.2 kg a.i./ha, the combination treatment with 2.2 kg a.i./ha of the nematicide applied in-furrow + banded, and the application of the chemical in a band alone at 3.3 kg a.i./ha. Factorial analysis of the phenamiphos data for subjective appearance revealed no interaction between the two methods of application but significant ($P = 0.01$) effects for band or in-furrow applications when each was considered independently of the other. Differences in incidence of white mold between treatments with nematicides and the control were not significant. Factorial analysis of the white mold results from phenamiphos treatments revealed no interaction between methods of application but a response to band applications when the data were considered independently of the effects from in-furrow applications.

Soybean.1. Aldicarb Experiment. Results from this experiment are presented in Table 3. The data show that when phenamiphos was applied in-furrow alone it did not result in yield increases above the control; however, all other nematicide treatments improved yields. Factorial analysis of the yield data from phenamiphos treatments showed no interaction between the methods of application but significant responses to in-furrow or banding applications when each was considered independently of the other. The only nematicide treatment that reduced larval populations was EDB 90 at 18.7 l/ha. Factorial analysis of the data on larvae revealed no effect from methods of application and no interaction between the two methods. All nematicide treatments resulted in improved values for the subjective appearance index compared with the control. The interaction between methods of application

Table 3. Effect of planting time applications of EDB 90 (Soilbrom® 90) and of combinations of in-furrow and banded treatments of aldicarb (Temik® 15G) on *Meloidogyne arenaria* and yield of Ransom soybean in a field experiment near Elberta, Alabama.

	Rate (kg a.i./ha) In-Furrow	Rate (kg a.i./ha) Band (18 cm)	Subjective[x] Appearance Index	Larvae per 100 cm^3 Soil	Yield (kg/ha)
Control			2.87 f[y]	161 a	584 e
Aldicarb 15G	1.1	0.0	3.50 e	107 ab	757 de
	2.2	0.0	3.75 de	181 a	773 de
	1.1	1.1	4.62 abc	98 ab	1306 bc
	1.1	2.2	4.50 abc	157 a	1168 bc
	2.2	1.1	4.75 ab	128 ab	1355 b
	2.2	2.2	4.37 bc	117 ab	1322 bc
	0.0	1.1	4.12 cd	131 ab	985 cd
	0.0	2.2	4.50 abc	102 ab	1139 bc
	0.0	3.3	4.75 ab	110 ab	1159 bc
	0.0	4.4	4.62 abc	178 a	1753 a
EDB 90 (1/ha)	9.35		4.75 ab	163 a	1241 bc
	18.70		5.00 a	51 b	2038 a

[x]The subjective appearance index was based on a scale of 1-5 where a value of 1 represented plots with severely stunted, chlorotic plants 45 days after planting; a value of 5 was ascribed to plots with plants showing excellent growth and no stunting.

[y]Means within the same column followed by a common letter were not statistically different ($P = 0.05$).

Table 4. Effect of planting time applications of EDB 90 (Soilbrom® 90) and of combinations of in-furrow and banded treatments of phenamiphos (Nemacur® 15G) on *Meloidogyne arenaria* and yield of Ransom soybean in a field experiment near Elberta, Alabama.

	Rate (kg a.i./ha)		Subjective[x] Appearance Index	Larvae per 100 cm^3 Soil	Yield (kg/ha)
	In-Furrow	Band (18 cm)			
Control			3.00 f[y]	74 bc	342 h
Phenamiphos	1.1	0.0	3.50 e	146 ab	541 gh
	2.2	0.0	3.50 e	126 abc	492 gh
	1.1	1.1	3.87 de	161 ab	989 cde
	1.1	2.2	4.25 bc	147 ab	960 de
	2.2	1.1	4.12 cd	89 bc	944 ef
	2.2	2.2	4.12 cd	92 bc	1225 bc
	0.0	1.1	4.00 cd	145 ab	704 fg
	0.0	2.2	4.25 bc	186 a	797 ef
	0.0	3.3	4.50 b	117 abc	1220 bc
	0.0	4.4	4.50 b	94 bc	1200 bcd
EDB 90 (l/ha)	9.35		4.87 a	143 ab	1404 b
	18.70		5.00 a	44 c	2347 a

[x]The subjective appearance index was based on a scale of 1-5 where a value of 1 represented plots with severely stunted, chlorotic plants 45 days after planting; a value of 5 was ascribed to plots with plants showing excellent growth and no stunting.
[y]Means within the same column followed by a common letter were not statistically different ($P = 0.05$).

for the subjective appearance data from aldicarb treatments was not significant; factorial analysis of the data showed significant effects in response to in-furrow or band applications.

2. Phenamiphos Experiment. Results from the phenamiphos experiment are presented in Table 4. All nematicide treatments but those with simple in-furrow applications of phenamiphos resulted in increased yields. Factorial analysis of the yield data from phenamiphos treatments showed no interaction between methods of application but significant responses to in-furrow or banded applications when data for each of the methods was considered independently. Numbers of larvae were higher in plots that received simple banded applications of phenamiphos at 2.2 kg a.i./ha than the numbers found in control plots; differences between larval numbers for the other nematicide treatments and those in control plots were not significant. Factorial analysis of the data on larvae from treatments with phenamiphos did not reveal any interaction or effects from in-furrow or banded applications. All treatments increased values for the subjective appearance index. Factorial analysis of the data on subjective appearance revealed no interaction between methods of application or effects attributable to in-furrow applications; however, when data for banded applications were considered independently of the effect of in-furrow applications a significant response was revealed.

DISCUSSION

Earlier work with peanuts and soybeans to determine the effect of application methods on the efficacy of four systemic nematicides (aldicarb, carbofuran, oxamyl, phenamiphos) showed that in-furrow applications were generally less efficacious than banded applications for control of *M. arenaria* and for yield response (20). The difference in efficacy depended on the width of the application band and, for some nematicides on the rate of application. These findings were interpreted as being the result of the systemic nature of the nematicides and their solubility in water. The four nematicides tested possess water solubilities that ranged from as low as 450 ppm (25°C) for phenamiphos to as high as 28% (w/w) for oxamyl (8). This range of solubility is apparently sufficient to assure good diffusion of the nematicides through the soil. When the nematicides are applied to soil very little lateral diffusion can be expected and most of the movement occurs vertically through the soil profile. Consequently, methods of application that result in movement of the nematicide through the space in the soil profile where most of the roots of the developing crop plants are growing, or will occupy, can be expected to result in good absorption of the nematicide by the plant, nematode control by direct contact toxicity and through systemic activity, and consequent yield increases (1,7). In the present study we chose band widths for peanuts and soybeans that were optimal for efficacy of aldicarb and phenamiphos based on previous results (20). The inclusion of an in-furrow rate within a banded treatment can be expected to increase the concentration of the material in the center of the treated soil area, thus increasing the concentration of nematicide available for absorption by the roots of the plant soon after germination. While this was thought to improve the performance of banded nematicide treatments against nematodes, our results do not support the assumption. Thus, for both aldicarb and phenamiphos, the combination treatments did not result in yield increases or nematode control that were significantly higher than those obtained from plots treated with equivalent or lower rates of the nematicides applied in simple band treatments. Indeed, some combination treatments resulted in lower yields than the simple banded treatments with equivalent dosages. This may be the result of inconspicuous phytotoxic effects from the in-furrow portion of the combined treatment. However, it is also more likely that the simple banded applications resulted in a more uniform distribution of the material through the soil profile than the distribution resulting from the combined treatments. A more uniform distribution of the nematicide in the soil can minimize phytotoxic effects and result in distribution through a broader section of the root system.

Our results corroborate findings from earlier work in which banded applications were shown to be superior to in-furrow applications for control of root-knot nematodes and yield response in peanut and soybean (20). In the present study this difference was more obvious in the soybean experiments than in those with peanut. This may be because the severity of nematode damage was considerably greater in the soybean experiments than in the peanut studies. Indeed, in the case of the phenamiphos experiment many soybean plants in control plots were dead by midseason which explained the low populations of larvae found in the soil samples taken later from these plots.

We observed some reduction in the incidence of white mold in response to several aldicarb treatments in peanuts. We have observed this effect before (22) although we have no explanation for it. It is possible that aldicarb may possess antifungal properties against *S. rolfsii* similar to those reported for other nematicides (15); however, more research is needed to determine the cause of the observed effect.

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Received for publication:
19.II.1982
Recibido para publicar: