Annals of Applied Nematology 2:95–101. 1988.

Efficacy of Fumigant and Nonfumigant Nematicides for Control of *Meloidogyne arenaria* on Peanut

D. W. Dickson and T. E. Hewlett[1]

Abstract: Three tests were conducted to evaluate the efficacy of fumigant and nonfumigant nematicides for control of *Meloidogyne arenaria* race 1 on peanut. Methyl bromide, 1,3-D, methyl isothiocyanate, and methyl isothiocyanate mixtures were applied 7 or 8 days preplant either broadcast or in-the-row. Aldicarb, ethoprop, fenamiphos, and F5145 were applied at different rates and by different methods at-plant or at early flowering. Of the 32 treatments evaluated, only seven resulted in yield increases ($P = 0.05$), although early season vigor was high in all treated plots. During the latter one-third of the growing season, however, nematode control was not adequate in most treatments resulting in heavy peg, pod, and root infection by *M. arenaria*.
Key words: 1,3-D, aldicarb, *Arachis hypogaea,* chemical control, ethoprop, F5145, fenamiphos, fumigant, *Meloidogyne arenaria,* methyl bromide, methyl isothiocyanate, nematicide, nonfumigant, peanut, root-knot nematode.

Meloidogyne arenaria (Neal) Chitwood is the most important soil pest of peanut in Florida (2). Field microplot experiments demonstrated that initial population densities of *M. arenaria* race 1 as low as two juveniles per 100 cm^3 soil cause yield loss of peanut (1). Consequently, controlling this nematode in sandy soils has often increased yields by more than 1,120 kg/ha (3). Traditionally, management practices for *M. arenaria* in the southeastern United States have relied on crop rotations (7) and nematicides (3). There is a need for continued evaluation of alternative nematicides. The objective of this study was to evaluate fumigant, nonfumigant, and methyl bromide nematicides for control of *M. arenaria* and improved peanut yield.

Materials and Methods

Three experiments were conducted in 1987 in adjacent fields at the Agricultural Research Center near Live Oak, Florida. The soil was a Blanton fine sand, 94% sand, 4% silt, 2% clay, 1.4% organic matter; pH 6.1. The fields were infested with *M. arenaria* race 1 cultured on tomato (*Lycopersicon esculentum* Mill. cv. Rutgers) and injected 20 cm deep at the rate of 210 and 280 eggs and juveniles per meter of row in 1985 and 1986, respectively. An indigenous population of *Criconemella ornata* (Raski) Luc and Raski was present in the fields. After nematode infestation in 1985, soybean (*Glycine max* (L.) Merr. cv. Centennial and Davis 1:1 mix), hairy vetch (*Vicia villosa* Roth.), peanut (*Arachis hypogaea* L. cv. Florunner), and rye (*Secale cereale* L. cv. Wrens Abruzzi) were grown in succession.

In preparation to plant peanut, the fields were moldboard plowed 36 cm deep 20 March and 672 kg/ha 0-10-20 (N-P-K) was applied broadcast. Other cultural practices and control of weeds, insects, and foliar diseases of peanut were based on local practices (12). The herbicides benefin (9.4 liters/ha) and vernolate (3.5 liters/ha) were tank mixed and applied broadcast preplant, and paraquat (0.8 liter/ha) was applied when seedlings were breaking through the soil. Chlorpyrifos (14.9 g/100 m in 36-cm band) was applied 11 June for control of lesser corn-stalk borer (*Elasmopalpus lignosellus* Zeller), and chlorothalonil (1.75 liters/ha) was applied six times at 14-day intervals beginning 27 days after planting for leafspot (*Cercospora arachidicola* Hori and *Cercosporidium personatum* Berk. & Curt [Deighton]) control.

The fumigant nematicides were SN 556 (40% methyl isothiocyanate [MIT]), CO 562 (30% methyl isothiocyanate, 70% 1,3-D), SN 530, the standard formulation

Received for publication 28 March 1988.
Florida Agricultural Experiment Station Journal Series No. 9137.
[1] Professor and Biological Scientist III, Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611-0611.

of MIT (20% methyl isothiocyanate, 40% 1,3-D) (Nor-am Chemical Company, Wilmington, DE), and 1,3-D. They were applied 25-cm deep 7 or 8 days preplant with swept-back chisels and a positive-flow power-take-off pump applicator. Six chisels spaced 30 cm apart were used for broadcast application; the chisel slits were sealed with press wheels. Applications in the row were made with two chisels spaced 20 cm apart centered over the row followed by disk-hillers angled to throw a 30-cm ridge of soil over the treated row. The ridges were knocked down to level before planting. Aldicarb (15 G) was applied at-plant as a standard.

Methyl bromide formulations were 68.6% methyl bromide and 1.4% chloropicrin in a low volatile petroleum based solvent and 68.6% methyl bromide and 1.4% chloropicrin in a nonvolatile diluent (GLC 682, Great Lakes Corp., West Lafayette, IN). They were metered through a varea-meter (Pennwalt, Belleville, NJ) from a nitrogen gas pressurized closed system applicator. The liquid was released 25 cm and 50 cm deep in each row with a subsoiler chisel plow fitted with bedding disks to seal the slits. Aldicarb was applied at early flowering over the medium rate of both methyl bromide formulations and also alone as a standard at planting.

The nonfumigant nematicides were aldicarb, ethoprop (15 G), fenamiphos (15 G), and F5145 (5 G) (FMC Corp., Philadelphia, PA). They were applied at planting on 13 May in a 30-cm or 36-cm band behind the planter opening disk and in front of the planter shoe, or in-furrow with a Gandy applicator (Gandy Company, Owatonna, MN), or by a hand-shaker jar. Aldicarb or fenamiphos were also applied at early flowering on 29 June in a 30-cm or 36-cm band directly over the vines with a Gandy applicator. A bag weighted at the bottom was dragged over the vines to dislodge granules from the foliage. 1,3-D was applied as a standard 7 days preplant.

Florunner peanut was planted 14 May. Soil samples for nematode assays were collected 54 and 118 days after planting. Each sample consisted of a composite of 12 2.5-cm-d cores (six/row) taken 20 cm deep in the root zone. Samples were thoroughly mixed and stored in plastic bags at 10 C until processed during a 5-day period after sampling. A 250-cm^3 aliquant of each sample was processed by a sugar flotation-centrifugation method (5). Soil temperature 15 cm deep was 26 C at time of application of fumigants and 24 C at planting.

Treatments were arranged in a randomized complete block design and plots consisted of two rows (nonfumigant and methyl bromide test) or four rows (fumigant test) 9 m long and spaced 76 cm apart. Treatments in the methyl bromide test were replicated four times, whereas those in the fumigant and nonfumigant tests were replicated six times. In each test the control plots were replicated double the other treatments.

On 10 October the inside two rows of four-row plots were dug, and 3 days later the entire plot area of the remaining plots were dug and the peanuts were combined. Yield data were taken after drying the peanuts to 12.5% moisture. All data were subjected to analysis of variance and treatment means were compared by Duncan's new multiple-range test (11). Unless otherwise stated all differences referred to in the text were significant at $P = 0.05$.

Results and Discussion

Fumigant test: Applications of SN 556, 1,3-D at 84 liters/ha, and CO 562 increased yields (Table 1). Numbers of *M. arenaria* at midseason and yields were inversely correlated ($r = -0.25$). The broadcast application of 1,3-D was superior to row application, but only the highest rate (84 liters/ha) increased yield compared with the control. SN 556 and CO 562 also increased yields. These formulations were superior to the standard formulation SN 530. All treatments except 1,3-D broadcast at 28 and 47 liters/ha resulted in lower numbers of *M. arenaria* juveniles in the soil at midseason compared with the control. The population density of *C. ornata* was not affected by any treatment.

Because of potential phytotoxicity, 1,3-D was applied 7 or 8 days preplant (6). The

TABLE 1. Peanut yield and average number of nematodes per 250 cm^3 soil 15 and 118 days after planting as affected by fumigant nematicides applied 25 cm deep compared with aldicarb at-plant.

Treatment and broadcast rate (a.i./ha)	Rate† a.i./30.5 m	Days preplant	Application method	Yield (kg/ha)	*Meloidogyne arenaria*		*Criconemella ornata*	
					54 DAP	118 DAP	54 DAP	118 DAP
Untreated				763 bc	199 a	2,300 abc	124 def	355 a
Aldicarb, 10 kg	31 g	0	30-cm band	1,067 abc	100 bc	1,977 bc	65 ef	209 a
1,3-D, 28 liters	86 ml/chisel	8	Broadcast	916 bc	230 a	2,039 abc	153 cde	265 a
1,3-D, 47 liters	143 ml/chisel	8	Broadcast	1,233 ab	167 ab	2,255 abc	299 a	223 a
1,3-D, 65 liters	200 ml/chisel	8	Broadcast	1,074 abc	109 bc	2,043 abc	287 ab	375 a
1,3-D, 84 liters	258 ml/chisel	8	Broadcast	1,394 a	45 c	2,076 abc	181 bcd	493 a
1,3-D, 140 liters	214 ml/chisel	7	Two chisels/row, diskhillers	709 c	57 c	1,653 c	255 abc	259 a
SN 530‡, 169 liters	258 ml/chisel	7	Two chisels/row, diskhillers	1,066 abc	35 c	3,165 ab	43 ef	427 a
SN 556, 169 liters	258 ml/chisel	7	Two chisels/row, diskhillers	1,398 a	33 c	3,500 a	38 ef	466 a
CO 562, 101 liters	154 ml/chisel	7	Two chisels/row, diskhillers	1,392 a	23 c	2,815 abc	30 f	461 a

Data are means of six replicates except untreated which are means of 12 replicates. Means with the same letter are not different ($P = 0.05$) according to Duncan's new multiple-range test.
† Rates were based on a 91.4-cm row spacing.
‡ SN 530 = 20% methyl isothiocyanate (MIT) and 40% 1,3-D; SN 556 = 40% MIT; CO 562 = 30% MIT and 70% 1,3-D.

TABLE 2. Peanut yield and average number of nematodes per 250 cm^3 soil 54 and 118 days after planting as affected by methyl bromide applied 25 cm and 50 cm deep, 7 days preplant compared with 1,3-D applied 25 cm deep, 7 days preplant and aldicarb at-plant.

Treatment and broadcast rate (a.i./ha)	Rate† a.i./30.5 m	Application method	Yield (kg/ha)	*Meloidogyne arenaria*		*Criconemella ornata*	
				54 DAP	118 DAP	54 DAP	118 DAP
Untreated			797 c	376 a	2,897 abc	121 a	654 b
Aldicarb, 10 kg	31 g	30-cm band	1,426 ab	224 ab	3,480 ab	55 bcd	538 b
1,3-D, 140 liters	214 ml/chisel	Two chisels/row, diskhillers	1,380 ab	28 b	2,464 abc	104 ab	1,648 a
Methyl bromide‡, 84 kg	0.26 kg	Subsoiler	983 bc	141 b	2,158 bc	46 cd	360 b
Methyl bromide, 168 kg	0.51 kg	Subsoiler	785 c	156 b	3,126 abc	39 cd	534 b
Methyl bromide, 252 kg	0.77 kg	Subsoiler	1,412 ab	39 b	2,786 abc	26 d	606 b
Methyl bromide, 168 kg + aldicarb§, 3.4 kg	0.51 kg + 10 g	Subsoiler, 36-cm band	1,559 a	62 b	1,378 c	33 d	722 b
GLC 682, 84 kg	0.26 kg	Subsoiler	781 c	90 b	4,096 a	88 abc	474 b
GLC 682, 168 kg	0.51 kg	Subsoiler	1,050 bc	45 b	3,876 ab	74 abcd	728 b
GLC 682, 252 kg	0.77 kg	Subsoiler	1,328 abc	35 b	2,904 abc	40 cd	394 b
GLC 682, 168 kg + aldicarb§, 3.4 kg	0.51 kg + 10 g	Subsoiler, 36-cm band	1,279 abc	19 b	2,454 abc	22 d	610 b

Data are means of four replicates except untreated which are means of eight replicates. Means with the same letter are not different ($P = 0.05$) according to Duncan's new multiple-range test.

† Rates were based on a 91.4-cm row spacing.

‡ Methyl bromide = 68.6% methyl bromide and 1.4% chloropicrin in a low volatile petroleum based solvent. GLC 682 = 68.6% methyl bromide and 1.4% chloropicrin in a nonvolatile diluent.

§ Applied at early flowering 29 June.

TABLE 3. Peanut yield and average number of nematodes per 250 cm^3 soil 54 and 118 days after planting as affected by nonfumigant nematicides applied in a band over the row at planting compared with 1,3-D applied 25 cm deep, 7 days preplant.

Treatment and broadcast rate (a.i./ha)	Rate† a.i./30.5 m	Application method	Yield (kg/ha)	*Meloidogyne arenaria*		*Criconemella ornata*	
				54 DAP	118 DAP	54 DAP	118 DAP
Untreated			1,087 ab	217 abc	2,978 a	100 abc	251 b
1,3-D, 140 liters	214 ml/chisel	Two chisels/row, diskhillers	1,075 ab	84 cd	1,867 bcd	107 ab	447 ab
Aldicarb, 10 kg	31 g	30-cm band	909 b	62 d	2,204 abcd	53 de	349 b
1,3-D, 140 liters + aldicarb‡, 6.7 kg	214 ml/chisel + 20 g	Two chisels/row, disk-hillers, 36-cm band	1,794 a	81 cd	1,332 d	124 a	633 a
Ethoprop, 13.4 kg	41 g	30-cm band	1,064 ab	202 abc	1,956 abcd	42 e	228 b
Ethoprop, 10 kg + aldicarb, 3.4 kg	31 g + 10 g	30-cm band, in-furrow	1,172 ab	165 bcd	1,863 bcd	55 de	324 b
Fenamiphos‡, 6.7 kg	20 g	30-cm band	1,425 ab	313 a	2,488 abc	89 abcd	224 b
Fenamiphos, 10 kg	31 g	30-cm band	1,237 ab	135 bcd	1,725 cd	60 cde	303 b
F5145, 7.5 kg	27 g	36-cm band	1,207 ab	226 ab	2,027 abcd	58 cde	276 b
F5145§, 15 kg	54 g	36-cm band, shaker jar	1,475 ab	269 ab	2,699 abc	71 bcde	308 b
F5145§, 22.4 kg	81 g	36-cm band, shaker jar	948 b	328 a	2,860 ab	68 bcde	376 ab

Data are means of six replicates except untreated which are means of 12 replicates. Means with the same letter are not different ($P = 0.05$) according to Duncan's new multiple-range test.
† All row rates except F5145 were based on a 91.4-cm row spacing. The rate for F5145 was based on a 101.6-cm row spacing.
‡ Applied at early flowering 19 June.
§ Applied with shaker jar because of the small amount of chemical available for testing.

efficacy of 1,3-D for controlling *M. arenaria* and increasing peanut yield is reportedly dependent on application depth (9). Our injection depth of 25 cm was in the range of the optimal application depth of 23 cm (9). Apparently the rates of 1,3-D that we evaluated were marginal for effective season-long suppression of population densities of *M. arenaria.* Similar rates of 1,3-D were also reported to be less effective than EDB (standard nematicide on peanut until suspended in 1983). Both DBCP (standard nematicide on peanut until suspended in 1977) and EDB had longer residual activity in soil than 1,3-D because of their lower vapor pressure and higher water solubility (4).

Methyl bromide test: Methyl bromide applied preplant plus aldicarb applied at early flowering, aldicarb applied at-plant, methyl bromide (252 kg a.i./ha) applied preplant, and 1,3-D applied preplant increased yields above the control (Table 2). All treatments except aldicarb applied at-plant resulted in a lower number of *M. arenaria* at midseason than occurred in the control. Seven of the ten treatments reduced the midseason population density of *C. ornata* compared with the control. The low volatile formulation of methyl bromide performed better than the nonvolatile formulation, although the yield among the three rates of each formulation were not different. Of the three rates of methyl bromide tested, only the high rate (252 kg a.i./ha) resulted in a yield higher than the control. Only the high rates of methyl bromide were reported to increase peanut yield in a *M. arenaria*-infested field in southern Alabama (10). The application of aldicarb at early flowering following methyl bromide or GLC 682 applied preplant increased yields by 99% over methyl bromide alone and 22% over GLC 682 alone.

Nonfumigant test: Yield of the control did not differ from all other treatments, although there was a 65% yield increase in plots treated with 1,3-D plus aldicarb applied at early flowering (Table 3). The addition of aldicarb at early flowering following 1,3-D applied preplant increased the yield 69% over that in the 1,3-D treated plots. The only treatment with a lower number of *M. arenaria* at midseason than occurred in the control was aldicarb applied at-plant. Population density of *C. ornata* was also lower in the control than occurred in plots treated with aldicarb and ethoprop at-plant and ethoprop at-plant plus aldicarb at early flowering.

Rainfall was below average during the test period, although there were no drought conditions. Three centimeters of water were applied by irrigation 10 June. A large increase in the *M. arenaria* population density occurred between the midseason and final nematode sampling date. This is shown by the large numbers of *M. arenaria* juveniles in all plots at harvest (Tables 1–3). This rapid buildup of juveniles on peanut during the final month before harvest has been reported previously (8). Also, a random survey of pegs, pods, and roots from five plants per plot taken immediately after digging showed 50–75% galling.

Chemical control as a single nematode management stratagem on peanut is not always reliable because of the crop's relatively long growing period and the susceptibility of pods and pegs up to harvest. In this study the effect of preplant application of soil fumigants on peanut yield was generally enhanced when combined with an early flowering application of a nonfumigant. Combination treatments with 1,3-D applied preplant and aldicarb applied at-plant also increased peanut yield (6).

Literature Cited

1. Candanedo-Lay, E. M. 1986. Penetration, damage, and reproduction of *Meloidogyne arenaria* on peanut. Ph.D. dissertation, University of Florida, Gainesville.

2. Dickson, D. W. 1985. Nematode diseases of peanut. Nematology circular No. 121, Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville.

3. Dunn, R. A. 1988. Peanut nematode management. Nematology plant protection pointer 11, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

4. Hague, N. G. M., and S. R. Gowen. 1987. Chemical control of nematodes. Pp. 131–178 *in* R. H. Brown and B. R. Kerry, eds. Principles and practice of nematode control in crops. New York and Sydney: Academic Press.

5. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

6. 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.

7. Rodríguez-Kábana, R., and H. Ivey. 1986. Crop rotation systems for the management of *Meloidogyne arenaria* in peanut. Nematropica 16:53–63.

8. Rodríguez-Kábana, R., C. F. Weaver, D. G. Robertson, and E. L. Snoddy. 1986. Population dynamics of *Meloidogyne arenaria* juveniles in a field with florunner peanut. Nematropica 16:185–196.

9. Rodríguez-Kábana, R., and D. G. Robertson. 1987. Control of *Meloidogyne arenaria* in peanut with 1,3-D: Relative efficacy and application depth. Nematropica 17:17–29.

10. Rodríguez-Kábana, R., D. G. Robertson, and P. S. King. 1987. Comparison of methyl bromide and other nematicides for control of nematodes in peanut. Annals of Applied Nematology (Journal of Nematology 19, Supplement) 1:56–58.

11. SAS Institute. 1985. SAS user's guide. SAS Institute, Cary, NC.

12. Whitty, E. B., W. L. Curry, T. C. Skinner, D. S. Harrison, R. P. Cromwell, F. A. Johnson, T. A. Kucharek, and R. A. Dunn. 1975. Peanut production guide. Circular 145F, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.