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Management of Plant-parasitic Nematodes on Peanut with Selected Nematicides in North Carolina[1]

S. R. KOENNING,[2] J. E. BAILEY,[2] D. P. SCHMITT,[3] AND K. R. BARKER[2]

Abstract: Field experiments were conducted to determine peanut growth and yield responses to selected fumigant and nonfumigant nematicide treatments in 1988 and 1989. All treatments with the fumigant 1, 3-D significantly suppressed nematode reproduction (*Meloidogyne arenaria, M. hapla,* and *Mesocriconema ornatum*) and enhanced peanut yields over the other treatments in four tests in 1988. Yield increases with the fumigant ranged from about 20% to 100% over the untreated control. Test sites in 1989 had lower nematode levels than those for 1988, and fewer positive plant and nematode responses were detected. Treatments with 1,3-D improved peanut quality but not yield in one experiment with low levels of *M. hapla* and *M. ornatum* in 1988. The 1,3-D + chloropicrin treatments at another site gave higher peanut yields than 1,3-D alone.

Key words: Arachis hypogaea, chemical control, management, *Meloidogyne arenaria, Meloidogyne hapla, Mesocriconema ornatum,* nematicides, nematode, peanut.

Several nematode species including *Meloidogyne arenaria* (Neal) Chitwood, *M. hapla* (Chitwood), *Belonolaimus longicaudatus* Rau, *Mesocriconema ornatum* (Raski) Loof & deGrisse, and *Pratylenchus brachyurus* (Godfrey) Filipjev and Schuurmans-Stekoven occur in various regions of the peanut (*Arachis hypogaea* L.) production area in the southeastern United States (Barker and Imbriani, 1984; Dickson and Hewlett, 1988; Phipps and Elliot, 1982; Rodríguez-Kábana et al., 1982, 1987a, 1987b; Rodríguez-Kábana and King, 1985; Rodríguez-Kábana and Robertson, 1987). Both *M. hapla* and *M. ornatum* have been shown to be highly damaging to peanut in microplots (Diomande et al., 1981). Although *M. arenaria* is less common on peanut in North Carolina than *M. hapla* (K. R. Barker, unpublished), reproduction and damage potentials of *M. arenaria* are greater (Koenning and Barker, 1992). Significant yield increases in field trials using the now-banned fumigant nematicides DBCP (1,2-dibromo-3-chloropropane) or EDB (ethylene dibromide) also clearly demonstrated the value of effective nematode control on peanut throughout the southeast (Phipps and Elliot, 1982; Sasser et al., 1975).

Plant-parasitic nematodes, including *M. arenaria* and *M. ornatum,* also can enhance damage caused by other soilborne pathogens of peanut. The severity of Cylindrocladium black rot (CBR), caused by *Cylindrocladium parasiticum,* is increased in the presence of both of these nematodes, including race 2 of *M. arenaria,* which does not reproduce on peanut (Diomande et al., 1981). Infection by *M. hapla* and race 1 of *M. arenaria* may negate the moderate level of resistance of NC 10C to this pathogen (Culbreath et al., 1992). Aldicarb suppressed the development of southern stem rot (white mold) caused by *Sclerotium rolfsii* on peanut in Alabama (Rodríguez-Kábana et al., 1987a) but not in Georgia in the presence of *M. arenaria* (Minton and Csinos, 1986).

Research conducted in North Carolina casts doubt on the economic value of some nonfumigant nematicides labeled for peanut. Aldicarb, carbofuran, ethoprop, and turbofos failed to give significant control of *C. ornata* and *M. hapla* or increase peanut yield during a 3-year study (Ayers et al., 1989).

Research conducted in Alabama, Georgia, Florida, and Texas involving primarily *M. arenaria* clearly demonstrated the damage potential of this nematode on peanut (Dickson and Hewlett, 1988; Huddleston and

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[2] Respectively, Senior Researcher, Professor, and Professor, Department of Plant Pathology, North Carolina State University, Raleigh, NC 27695-7616.
[3] Professor and Chairman, Department of Plant Pathology, University of Hawaii, 3190 Maile Way, Room 305, Honolulu, Hawaii 96822.
e-mail: srkpp@unity.ncsu.edu.

Jones, 1979; Minton and Csinos, 1986; Rodríguez-Kábana and King, 1985; Rodríguez-Kábana and Robertson, 1987; Rodríguez-Kábana et al., 1982, 1987a, 1987b; Wheeler and Starr, 1987). Peanut growth and yield were increased as a result of nematicide application (Dickson and Hewlett, 1988; Huddleston and Jones, 1979; Minton and Csinos, 1986; Phipps and Elliot, 1982; Rodríguez-Kábana and King, 1985; Rodríguez-Kábana and Robertson, 1987; Rodríguez-Kábana et al., 1975). Fumigant nematicides have been most efficacious in Georgia, Florida, Alabama, and Texas during most years, and certain nonfumigants, especially aldicarb during dry seasons, also have given excellent nematode control and yield responses. Chemical soil treatment involving two applications, one at planting and the second at pegging, has given promising but variable results (Dickson and Hewlett, 1988).

Although considerable progress has been made toward quantifying the magnitude of peanut-yield losses due to nematodes (Koenning and Barker, 1992; McSorley et al., 1992), research is still needed to characterize the damage thresholds and the efficacy of various chemical soil treatments in different nematode communities, especially those including *M. ornatum* and *M. arenaria* in North Carolina. The latter nematode is becoming more prevalent in North and South Carolina (Fortnum et al., 1984; Schmitt and Barker, 1988). This study was initiated to determine the relative efficacy of selected nematicides and subsoiling for control of *M. hapla, M. arenaria,* and *M. ornatum* on peanut.

Materials and Methods

Eight experiments were conducted in North Carolina fields infested with one or more of the species *M. hapla, M. arenaria,* and *M. ornatum.* Four of these experiments conducted in 1988 included sites in Bladen County (*M. arenaria, M. hapla,* and *M. ornatum;* Norfolk loamy fine sand, 89% sand, 10% silt, 1% clay), Martin County (*M. arenaria* and *M. ornatum;* Goldsboro fine sandy loam 86% sand, 13% silt, 1% clay), Gates County (*M. arenaria;* Lenoir very fine sandy loam, 67% sand, 26% silt, 7% clay), and Northampton County (*M. hapla* and *M. ornatum;* Ruston fine sandy loam, 60% sand, 34% silt, 6% clay). The remaining tests were conducted in 1989; two in Martin County (site 1: Goldsboro fine sandy loam, 79% sand, 17% silt, 4% clay; site 2: Goldsboro loamy sand 89% sand, 8% silt, 3% clay) and two in Northampton County (site 3: Norfolk fine loamy sand, 82% sand, 16% silt, 2% clay; site 4: Marlboro fine sandy loam, 66% sand, 28% silt, 6% clay). All field sites in 1989 were infested with *M. hapla,* and *M. ornatum* was detected at sites 1, 3, and 4. Experiments in 1988 had 13 treatments arranged in a randomized complete block design with 4 replications. Numbers of treatments and replications in 1989 varied per test; Northampton County (sites 3 and 4) had 8 treatments with 6 replications, Martin County (site 1) had 4 treatments and 5 replications with two cultivars, and the other experiment in Martin County (site 2) had 8 treatments with 4 replications. The plots each year were 4 rows on 92-cm centers, 15-m long. Data collection was from the center two rows.

All plots treated with nematicides and an untreated control were subsoiled in 1988. One untreated control was not subsoiled. Nematicides evaluated in 1988 were: aldicarb (0.56, 2.24, and 2.36 kg/ha [0.51, 0.205, and 0.307 g/m of row, respectively]), fenamiphos (2.24 kg/ha [0.205 g/m of row]); ethoprop (3.36 kg/ha [0.307 g/m of row]); chlorpyrifos 4E (3.36 and 5.60 kg/ha [0.307 and 0.512 g/m of row, respectively]); 1,3-D (28 liters/ha [2.56 ml/m of row] and 56 liters/ha [5.12 ml/m of row]) alone and in combination with aldicarb (0.56 kg/ha). Treatments in Northampton County in 1989 were fenamiphos and aldicarb (2.24 kg/ha [0.205 g/m of row]), 1,3-D (37.4 and 56 liters/ha [3.4 and 5.12 ml/m of row]), 1,3-D + chloropicrin (46.8 and 70.1 liters/ha [4.28 and 6.41 ml/m of row]), and metam-sodium (93.5 liters/ha [8.55 ml/m of row]). Nematicide treatments in Martin County (site 1) in 1988 included fenamiphos and aldicarb at 2.2 kg/ha (0.20 g/m of row), 1,3-D at 56.0

liters/ha (5.13 ml/m of row), and an untreated control. A 2 × 6 factorial experiment was conducted in 1989 in Martin County (site 1) with two cultivars, NC 7 and NC 10C, and five fumigant treatments plus a control. The fumigants 1,3-D, 1,3-D plus chloropicrin, and metam-sodium were delivered through a hydraulic-operated meter and applied to a depth of 36 cm with a commercial subsoiler. The granular materials were applied with a commercial applicator. Chlorpyrifos was applied in a 30-cm-wide band and incorporated approximately 10 cm deep. The other nonfumigants were applied in an 18-cm-wide band on the soil surface and incorporated with rolling tines.

Fumigants were applied 21 April 1988 in Bladen County, 18 April 1988 in Martin County, 26 April 1988 in Gates County, 25 April 1988 in Northampton County, and 24 April 1989 in Martin and Northampton counties. Nonfumigants were applied and peanuts were planted on 13 May 1988 in Northampton County and Gates County, 9 May 1988 in Martin County, 12 May 1988 in Bladen County, 22 May 1989 in Martin County, and 23 May 1989 in Northampton County. The peanut cultivar NC 7 was used in all experiments, except the factorial experiment in Martin County, which also used NC 10C.

Seed beds were prepared with conventional tillage and bedding. Weed control and routine maintenance of the plots were performed by the growers according to standard practices for North Carolina. Rainfall was the only source of water in every test.

All data were taken from the center two rows of each plot. Ten to twelve 2.5-cm-diam. soil cores were taken to a depth of 20 cm in the row and composited immediately prior to fumigation and at midseason (15 August through 23 August). Nematodes were extracted from 500 cm^3 soil by a combination of elutriation (Byrd et al., 1976) and centrifugation (Jenkins, 1964). Eggs were extracted from roots with an NaOCl method (Byrd et al., 1972) in 1988, but not in 1989. Peanuts were harvested from the entire length of the two center rows at all sites with a commercial peanut harvester.

Data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS (SAS Institute, Cary, NC). Nematode data were transformed (log 10 [x + 1]) to standardize the variance prior to analysis. Untransformed data are presented in tables. The Waller-Duncan k-ratio *t*-test and orthogonal contrasts were used to compare treatment means. Correlation coefficients were calculated for midseason population densities of nematodes and peanut yield.

Results and Discussion

Highest yields were achieved with the fumigant nematicides (Tables 1,2). Plots treated with fumigants gave higher yields at all locations in 1988 compared with the nonfumigant nematicides in 1988 (Table 1). The 56-liter/ha rate of 1,3-D improved yields over the 28-liter/ha rate in Martin Country in 1988. The average yield with all nematicides in Northampton County was greater ($P < 0.05$) than the untreated controls. Cylindrocladium black root rot was positively correlated with midseason numbers of root-knot nematode at the Bladen County location in 1988 ($r = 0.25$, $P < 0.05$). Subsoiling had little effect on peanut yields, and subsoiled controls were not different from unsubsoiled controls. Sclerotinia blight caused by *Sclerotinia minor* was enhanced in fumigant-treated plots in 1988 at the Gates County site (data not included).

The fields selected for the 1989 tests had lower nematode population densities than those used in 1988. In one Martin County test (site 1), where very low numbers of *M. hapla* and *M. ornatum* were found, significant differences in peanut yield were not detected in the experiment, although plots fumigated with 1,3-D at 56 liters/ha produced the highest quantity of peanuts (Table 2). In the 1989 Northampton County tests (sites 3 and 4), 1,3-D plus chloropicrin effected higher yields than 1,3-D without chloropicrin (Table 2). Treatment with 56 liters/ha of 1,3-D suppressed disease caused by *Cylindrocladium parasiticum* in Martin County.

In an experiment to evaluate the interaction of *M. hapla* with *Cylindrocladium*

TABLE 1. Yield of peanut 'NC 7' in response to nematicide treatment of soil at four sites infested with *Meloidogyne hapla, M. arenaria,* and *Mesocriconema ornatum,* 1988.

	Dosage			Yield (kg per ha)[b]			
Nematicide[a]	Per meter of flow	Per hectare	Application	Bladen	Gates	Martin	Northampton
Control (not subsoiled)	—	—	—	1,497 a	3,336 a	1,094 ab	1,729 d
Control (subsoiled)	—	—	—	1,501 a	3,214 a	867 b	2,038 bcd
1,3-D	2.56 ml	28.0 l	IPP	3,165 a	4,040 a	1,188 b	2,604 abc
1,3-D	5.13 ml	56.0 l	IPP	2,832 a	3,503 a	2,002 a	3,113 a
1,3-D + aldicarb	2.56 ml +0.05 g	28.0 l +0.56 kg	IPP + 18B	2,828 a	3,410 a	1,225 ab	2,758 ab
1,3-D + aldicarb	5.13 ml +0.05 g	56.0 l +0.56 kg	IPP + 18B	2,641 a	3,934 a	1,489 ab	3,003 a
Aldicarb	0.05 g	0.56 kg	18B	972 a	3,194 a	753 b	2,132 bc
Aldicarb	0.2 g	2.2 kg	18B	2,201 a	2,840 a	1,265 ab	1,912 cd
Aldicarb	0.31 g	3.4 kg	18B	915 a	3,031 a	1,042 ab	2,311 abcd
Fenamiphos	0.20 g	2.2 kg	36B	2,543 a	3,206 a	899 b	1,973 bcd
Ethoprop	0.31 g	3.4 kg	36B	1,762 a	2,636 a	1,294 ab	2,120 bcd
Chlorpyrifos	0.31 g	3.4 kg	36B	1,741 a	2,868 a	952 b	2,502 abcd
Chlorpyrifos	0.51 g	5.6 kg	36B	3,104 a	2,824 a	1,099 ab	2,136 bcd
Orthogonal contrasts[c]				A	A	A,B	A,C

Data are means of six replicates; means in columns followed by the same lowercase letter do not differ according to the Waller-Duncan k-ratio *t*-test (k-ratio = 100).

[a] All plots treated with nematicides were in-row subsoiled. Dosages are expressed as active ingredient for nonfumigants and as formulated product for fumigants. 36B = placed in a 36-cm-wide band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting; 18B = placed in an 18-cm-wide band directed in front of the press wheel.

[b] Nematodes present per county were: Bladen—*M. hapla, M. arenaria, M. ornatum;* Gates—*M. arenaria;* Martin—*M. arenaria, M. ornatum;* Northhampton—*M. hapla, M. ornatum.*

[c] Letters are used to designate differences in yields as determined by orthogonal contrasts at $P < 0.05$. A = fumigants vs. nonfumigants; B = 1,3-D (28 liter) vs. 1,3D (56 liter); C = controls vs. nematicide treatments.

parasiticum, the *Cylindrocladium*-resistant cultivar, NC 10C, produced far superior yields than the susceptible cultivar, NC 7 (Table 3). Using 1,3-D plus chloropicrin at 70.1 liters/haresulted in higher yields than 1,3-D plus chloropicrin at 48 liters/ha ($P = 0.05$).

Peanut yield in 1988 was negatively correlated with midseason numbers of *M. arenaria*

TABLE 2. Influence of nematicides on peanut 'NC 7' yield in fields with low initial populations of *Meloidogyne hapla,* 1989.

	Dosage[b]			Yield (kg per ha)		
Nematicide[a]	Per meter of flow	Per hectare	Application	Site 1	Site 3	Site 4
Fenamiphos	0.20 g	2.2 kg	36B	2,177	3,350	3,180
Aldicarb	0.20 g	2.2 kg	36B	1,933	3,594	2,516
1,3-D	3.42 ml	37.4 l	IPP	—	3,540	2,848
1,3-D	5.13 ml	56.0 l	IPP	2,573	3,343	2,679
1,3-D + Chloropicrin	4.28 ml	48.8 l	IPP	—	3,791	3,336
1,3-D + Chloropicrin	6.41 ml	70.1 l	IPP	—	3,858	3,207
Metam-sodium	8.55 ml	93.5 l	IPP	—	3,641	2,868
Control	—	—	—	1,953	3,540	3,194
Orthogonal contrasts[c]	—	—	—			A,B,C

Data are means of six replications at Northampton County (sites 3 and 4) and four replications at Martin County site (site 1).

[a] All plots treated with nematicides were in-row subsoiled.

[b] Dosages of nonfumigants are expressed as active ingredients and fumigants as formulated product. 36B = placed in a 36-cm-wide band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting; 18B = placed in an 18-cm-wide band directed in front of the press wheel.

[c] Letters are used to designate differences in yields as determined by orthogonal contrasts at $P < 0.05$. A = 1,3-D vs. 1,3-D + chloropicrin; B = fenamiphos vs. aldicarb.

TABLE 3. Peanut 'NC 10C' and 'NC 7' yields in a field in Martin County, North Carolina (site 2), infested with *Meloidogyne hapla* and *Cylindrocladium parasiticum*, 1989.

Nematicide[a]	Dosage: Ml per meter of row	Dosage: Liters per hectare	Cultivar: 'NC 7'	Cultivar: 'NC 10C'
1,3-D	3.42	37.4	1,416	2,677
1,3-D	5.13	56.0	1,074	2,645
1,3-D + Chloropicrin	4.28	48.8	1,009	2,140
1,3-D + Chloropicrin	6.41	70.1	846	3,076
Metam-sodium	8.55	93.5	1,082	2,417
Control	—	—	1,139	2,669
Orthogonal Contrasts[b]			A	A,B

Data are means of five replications.

[a] All treatments were subsoiled; the chemicals were injected 35 cm deep 28 days prior to planting.

[b] Letters used to designate differences in yield as determined by orthogonal contrasts at $P < 0.05$. A = NC 10C vs. NC 7; B = 1,3-D + Chloropicrin at 48.8 liters/ha vs. 70.1 liters/ha.

and *M. ornatum* ($r = -0.42$, $P = 0.01$ and $r = 0.55$, $P = 0.01$, respectively) in Martin County. Similarly, peanut yield in 1988 was negatively correlated to midseason numbers of root-knot nematodes at both the Bladen County site ($r = 0.31$, $P = 0.01$) and the Gates County site ($r = 0.549$, $P = 0.0001$). Midseason population densities of plant-parasitic nematodes were not related to peanut yield at the Northampton County site in 1988 or at any of the sites used in 1989.

Fumigant nematicides were fairly consistent in suppressing root-knot nematode populations at all sites except Bladen County in 1988 (Table 4) based on the numbers of eggs and juveniles per 500 cm^3 soil.

TABLE 4. Numbers of *Meloidogyne* spp. eggs and juveniles per 500 cm^3 soil at midseason (early September 1988) at four locations. *Meloidogyne* spp. at the various sites were: Bladen County (*Meloidogyne hapla* and *M. arenaria*), Gates and Martin counties (*M. arenaria*), and Northampton County (*Meloidogyne hapla*).

Nematicide[a]	Dosage[b]: Per meter of row	Dosage[b]: Per hectare	Dosage[b]: Application	*Meloidogyne* spp. eggs and juveniles per 500 cm^3 soil: Bladen County	Gates County	Martin County	Northampton County
Control (not subsoiled)	—	—	—	19,400	80,900	16,100	17,800
Control (subsoiled)	—	—	—	21,700	157,700	23,800	19,800
1,3-D	2.56 ml	28.0 l	IPP	14,100	25,200	4,800	17,100
1,3-D	5.13 ml	56.0 l	IPP	6,400	2,800	400	1,600
1,3-D + aldicarb	2.56 ml +0.05 g	28.0 l +0.56 kg	IPP + 18B	17,800	80,100	2,100	13,500
1,3-D + aldicarb	5.13 ml +0.05 g	56.0 l +0.56 kg	IPP + 18B	13,700	15,400	100	1,000
Aldicarb	0.2 g	2.2 kg	18B	11,400	81,700	15,300	13,500
Aldicarb	0.05 g	0.56 kg	18B	16,600	168,100	8,100	19,000
Aldicarb	0.31 g	3.4 kg	18B	35,400	139,800	10,100	10,600
Fenamiphos	0.20 g	2.2 kg	36B	10,700	118,700	6,600	13,000
Ethoprop	0.31 g	3.4 kg	36B	16,500	162,300	12,800	25,000
Chlorpyrifos	0.31 g	3.4 kg	36B	23,300	51,300	21,900	24,400
Chlorpyrifos	0.51 g	5.6 kg	36B	16,600	93,800	21,000	49,500
Orthogonal contrasts[c]				c	a,B,c	A,B,C	B,C,D

Data are means of six replications.

[a] All plots treated with nematicides were in-row subsoiled.

[b] Dosages are expressed as active ingredients for nonfumigants and formulated product for fumigants. 36B = placed in a 36-cm-wide band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting; 18B = placed in an 18-cm-wide band directed in front of the press wheel.

[c] Letters at the end of a column designate orthogonal contrasts. Uppercase letters denote significance of contrasts at $P = 0.05$; lowercase $P = 0.05$–0.10. Contrasts: A = control vs. nematicide treatments; B = fumigants vs. nonfumigants; C = 1,3-D at 28 liters/ha vs. 1,3-D at 56.0 liters/ha; D = 1,3-D at 28 liters/ha + aldicarb vs. 1,3-D at 56.0 liters/ha + aldicarb.

The higher rate of 1,3-D (56.0 liters/ha vs. 28.0 liters/ha) resulted in lower midseason population densities of both *Meloidogyne* spp. and *M. ornatum* at all 1988 sites (Tables 4,5). Fumigant nematicides gave superior control of *M. ornatum* compared to nonfumigant nematicides at all sites except the Northampton County site (Table 5). Aldicarb at 3.4 kg/ha gave better control of *M. ornatum* than did the 2.2/kg/ha rate at Northampton County in 1988.

Nematode suppression was similar in 1989 to that achieved in 1988, based on midseason population densities of second-stage juveniles of *M. hapla* and all stages of *M. ornatum* with the various nematicides evaluated. Fumigants gave greater nematode control than nonfumigants (Tables 6,7). The halogenated hydrocarbon fumigants 1,3-D and 1,3-D + chloropicrin were superior to metam-sodium for control of *M. hapla* based on midseason nematode numbers. Nematode suppression was greater with 1,3-D + chloropicrin than with 1,3-D at site 4, but the reverse was true for site 3. Suppression of *M. ornatum* at site 3 by nematicides was similar to the suppression achieved with *M. hapla,* although fenamiphos was more effective than aldicarb in controlling *M. ornatum* based on orthogonal contrasts (Table 7). Differences in nematode control by various nematicides were much greater at site 3 compared to site 4 in Northampton County. The only significant orthogonal contrast for site 4 in Northampton County was for 1,3-D + chloropicrin vs. 1,3-D for both *M. hapla* and *M. ornatum* (Tables 6,7).

The population levels of both *Meloidogyne* spp. in some of the peanut fields were above reported damage thresholds (Barker, 1974; Rodríguez-Kábana and King, 1985; Rodríguez-Kábana et al., 1982). Based on the results reported herein and those of others (Huddleston and Jones, 1979; Koenning and Barker, 1992; McSorley et al., 1992; Minton and Csinos, 1986; Rodríguez-Kábana et al., 1982, 1987a, 1987b), *M. arenaria* is an important pathogen of peanut. The presence of other pathogens, especially *C. parasiticum, Sclerotinia minor,* and *Sclerotium rolfsii,*

TABLE 5. Influence of selected fumigant and nonfumigant nematicides on final densities of *Mesocriconema ornatum* per 500 cm³ of soil at three locations in 1988.

Nematicide[a]	Dosage[b] Per meter of row	Dosage[b] Per hectare	Application	*M. ornatum* per 500 cm³ soil: Bladen County	Martin County	Northampton County
Control (not subsoiled)	—	—	—	500	2,600	3,700
Control (subsoiled)	—	—	—	300	1,200	200
1,3-D	2.56 ml	28.0 l	IPP	700	1,500	2,100
1,3-D	5.13 ml	56.0 l	IPP	700	500	30
1,3-D + aldicarb	2.56 ml +0.05 g	28.0 l +0.56 kg	IPP + 18B	1,500	700	1,900
1,3-D + aldicarb	5.13 ml +0.05 g	56.0 l +0.56 kg	IPP + 18B	1,100	300	1,400
Aldicarb	0.2 g	2.2 kg	18B	300	1,300	2,400
Aldicarb	0.05 g	0.56 g	18B	600	2,400	700
Aldicarb	0.31 g	3.4 kg	18B	400	1,100	1,300
Fenamiphos	0.20 g	2.2 kg	36B	600	1,700	1,800
Ethoprop	0.31 g	3.4 kg	36B	500	2,900	1,300
Chlorpyrifos	0.31 g	3.4 kg	36B	700	900	1,800
Chlorpyrifos	0.51 g	5.6 kg	36B	900	1,300	800
Orthogonal Contrasts[c]				A,c	A,B	B,d

Data are means of six replications.

[a] All plots treated with nematicides were in-row subsoiled.

[b] Dosages are expressed as active ingredients for nonfumigants and formulated product for fumigants. 36B = placed in a 36-cm-wide band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting; 18B = placed in an 18-cm-wide band directed in front of the press wheel.

[c] Letters at the end of a column designate orthogonal contrasts. Uppercase letters denote significance of contrasts at $P = 0.05$; lowercase $P = 0.05$–0.10. Contrasts: A = fumigants vs. nonfumigants; B = 1,3-D at 28 liters/ha vs. 1,3-D at 56.0 liters/ha; C = 1,3-D vs. 1,3-D + aldicarb; D = aldicarb at 2.2 kg/ha vs. aldicarb at 3.4 kg/ha.

TABLE 6. Effects of fumigant and nonfumigant nematicides on numbers of second-stage juveniles (J2) of *Meloidogyne hapla* per 500 cm^3 of soil at two locations in Northampton County in 1989.

	Dosage[b]			*M. hapla* J2 per 500 cm^3 soil	
Nematicide[a]	Per meter of row	Per hectare	Application	Site 3	Site 4
Fenamiphos	0.20 g	2.2 kg	36B	1,100	90
Aldicarb	0.20 g	2.2 kg	36B	920	90
1,3-D	3.42 ml	37.4 l	IPP	50	230
1,3-D	5.13 ml	56.0 l	IPP	60	120
1,3-D + Chloropricrin	4.28 ml	48.8 l	IPP	150	90
1,3-D + Chloropicrin	6.41 ml	70.1 l	IPP	210	30
Metam-sodium	8.55 ml	93.5 l	IPP	2,040	110
Control	—	—	—	560	150
Orthogonal Contrasts[c]	—	—	—	A,B,C	NS

Data are means of six replicates.
[a] All plots treated with nematicides were in-row subsoiled.
[b] Dosages are expressed as active ingredients for nonfumigants and formulated product for fumigants. 36B = placed in a 36-cm band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting.
[c] Letters at the end of a column designate orthogonal contrasts. Uppercase letters denote significance of contrasts at $P = 0.05$, lowercase $P = 0.05$–0.10. Contrasts: A = control vs. nematicide treatments; B = fumigants vs. nonfumigants; C = 1,3-D at 28 liters/ha vs. 1,3-D at 56.0 liters/ha; D = 1,3-D vs. 1,3-D + chloropicrin.

often compounds the damage caused by nematodes (Culbreath et al., 1992; Diomande and Beute, 1981). Although *M. hapla* or *M. arenaria* may partially negate the CBR resistance in 'NC 10C' (Diomande et al., 1981), its performance was superior to CBR-susceptible 'NC 7'. Cultivars with multiple disease resistance are needed to alleviate the damage caused by the many interacting pathogens.

This research demonstrates the need for improved tactics and strategies for managing plant-parasitic nematodes in peanut. Nonfumigant nematicides did not perform well in the current study, which verifies previous research (Ayers et al., 1989). Fumigant

TABLE 7. Effects of fumigant and nonfumigant nematicides on numbers of *Mesocriconema ornatum* per 500 cm^3 of soil at two locations in Northampton County, North Carolina, in 1989.

	Dosage[b]			*M. ornatum*	
Nematicide[a]	Per meter of row	Per hectare	Application	Site 3	Site 4
Fenamiphos	0.20 g	2.2 kg	36B	1,700	230
Aldicarb	0.20 g	2.2 kg	36B	5,390	540
1,3-D	3.42 ml	37.4 l	IPP	1,100	1,790
1,3-D	5.13 ml	56.0 l	IPP	60	1,170
1,3-D + Chloropicrin	4.28 ml	48.8 l	IPP	190	310
1,3-D + Chloropicrin	6.41 ml	70.1 l	IPP	1,100	430
Metam-sodium	8.55 ml	93.5 l	IPP	1,770	620
Control	—	—	—	1,220	860
Orthogonal Contrasts[c]	—	—	—	B,C,D,F,G,H	E

Data are means of six replications; means in a column followed by the same letter do not differ, Waller-Duncan k-ratio *t*-test (k-ratio = 100).
[a] All plots treated with nematicides were in-row subsoiled.
[b] Dosages are expressed as active ingredients for nonfumigants and as formulated product for fumigants. 36B = placed in a 36-cm-wide band and incorporated with a rolling tine mounted to the front of a commercial planter; IPP = injected 35 cm deep 17 to 21 days prior to planting.
[c] Letters at the bottom of columns are used to designate differences in yields as determined by orthogonal contrasts. Uppercase letters indicate significance at $P = 0.05$; lowercase letters at $P = 0.05$–0.10. Contrasts: A = control vs. nematicide treatments; B = fumigants vs. nonfumigants; C = 1,3-D and 1,3-D + chloropicrin vs. nonfumigants; D = 1,3-D and 1,3-D + chloropicrin vs. metam-sodium; E = 1,3-D vs. 1,3-D + chloropicrin; F = 1,3-D at 37.4 liters/ha vs. 1,3-D at 56.0 liters/ha; G = 1,3-D + chloropicrin at 48.8 liters/ha vs. 1,3-D + chloropicrin at 70.1 liters/ha; H = fenamiphos vs. aldicarb.

nematicides were effective, but the high cost associated with these products, as well as the necessary time interval between treatment and planting, may limit their acceptance by growers.

Future research should be devoted to developing peanut cultivars with resistance to *M. hapla, M. arenaria,* and *M. ornatum.* Alternative cropping systems that incorporate rotations with nonhosts or trap crops for these pathogens also should be developed.

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