Population Dynamics of Plant Nematodes in Cultivated Soil: Effects of Combinations of Cropping Systems and Nematicides[1]

W. S. MURPHY, B. B. BRODIE, and J. M. GOOD[2]

Abstract: The population density of *Meloidogyne incognita* was significantly reduced in land that was fallowed or cropped to crotalaria, marigold, bermudagrass, or bahiagrass. The rate of population decline caused by different cropping systems was influenced by initial population densities. Crotalaria, marigold, and bare fallow were about equally effective in reducing the density of *M. incognita* below detectable levels, usually requiring 1-3 yr. Bahiagrass and bermudagrass required 4-5 yr or longer to reduce *M. incognita* below a detectable level. A high population density of *Trichodorus christiei* developed in land cropped 5 yr to bermudagrass, bahiagrass, okra, and marigold. Population densities of *Pratylenchus brachyurus* and *Xiphinema americanum* increased in land cropped to crotalaria or bermudagrass. *Belonolaimus longicaudatus* was detected only in land cropped to bermudagrass. The effectiveness of nematicides in reducing *M. incognita* infection was related to nematode population density resulting from 5 yr of different cropping systems. Treatment with aldicarb reduced *M. incognita* below detectable levels following all cropping systems; treatment with ethoprop following all cropping systems except okra, treatment with ethylene dibromide following bahiagrass or fallow; and treatment with DBCP only after 5 yr of fallow. Tomato transplant growth was affected by both cropping systems and nematicide treatment. Transplants grown after crotalaria and bahiagrass were significantly larger than those grown after other crops. Also, treatment with aldicarb and ethoprop significantly increased transplant size. *Key Words:* crop rotation, chemical control, tomato transplants.

Two of the most commonly used and most effective practices for managing nematode populations at low densities are chemical soil treatment and crop rotation. Although either practice alone improves yields of many crops, there are undesirable features associated with each. Crop rotation designed to reduce a specific nematode species often does so at the expense of increasing other species to damaging levels (3, 4, 8, 11). Chemical soil treatment, which generally improves crop yields, rarely reduces nematode population densities for more than 2-3 mo, resulting in postharvest population densities greater than preplant densities (2).

Crop rotation is a successful farming practice, not only because of its beneficial soil-building effects, but also because nematode populations can be regulated (6). Crops that are effective against several species of *Meloidogyne* include crotalaria, millet, bermudagrass (cultivar 'Coastal'), bahiagrass, marigold, and sundangrass (7, 9, 12). However, continued growing of these crops increases other nematode species such as *T. christiei*, *X. americanum*, *P. brachyurus*, and *B. longicaudatus* (3, 4). These nematode species have been effectively controlled with such nematicides as DD, EDB, aldicarb, and ethoprop (1). In cases where zero detection of nematodes is sought, neither practice alone is adequate. Consequently, we studied the effect of a combination of cropping systems and chemical soil treatment on population densities of *Meloidogyne incognita* (Kofoid & White) Chitwood, *Trichodorus christiei* Allen, *Xiphinema americanum* Cobb, *Pratylenchus brachyurus* (Godfrey), Filip. & Schuur. Stekh., and *Belonolaimus longicaudatus* Rau.

MATERIALS AND METHODS

The experiment was established in land that had been abandoned for tomato transplant production because of an extremely high population density of *M. incognita*. The land also had a detectable infestation of *T. christiei*. Before the experiment was established, part of the land had been cropped 5 yr to okra (*Hibiscus esculentus* L.), part 5 yr to crotalaria (*Crotalaria mucronata* Desv.), and part for 5 yr in native pasture which consisted predominantly of common bermudagrass [*Cynodon dactylon* (L.) Pers.], centipedegrass [*Eremochloa ophiuroides* (Munro) Hacks.] and crabgrass (*Digitaria* spp.).

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[1]Cooperative investigations of the Agricultural Research Department, Campbell Institute for Agricultural Research; Agricultural Research Service, U.S. Department of Agriculture; and the University of Georgia College of Agriculture Experiment Stations, Coastal Plain Station, Tifton.

[2]Soil Scientist, Campbell Institute for Agricultural Research, West Chicago, Ill. 60185, and Nematologists, Agricultural Research Service, U.S. Department of Agriculture, Department of Plant Pathology, Cornell University, Ithaca, N.Y. 14850, and ARS, USDA, Beltsville, Md. 20705, respectively. All authors were stationed in Georgia when this research was performed.

Six cropping systems were arranged in a split-plot design replicated three times. Previous crops were main plots and newly imposed cropping systems were subplots. The plot size was 2.75 × 60 m for main plots and 2.75 × 12 m for subplots. The cropping systems included 5 yr of fallow, okra, crotalaria, marigold (*Tagetes erecta* L.), bermudagrass [*Cynodon dactylon* (L.) Pers. 'Coastal']; or bahiagrass (*Paspalum notatum* Fluegge 'Pensacola').

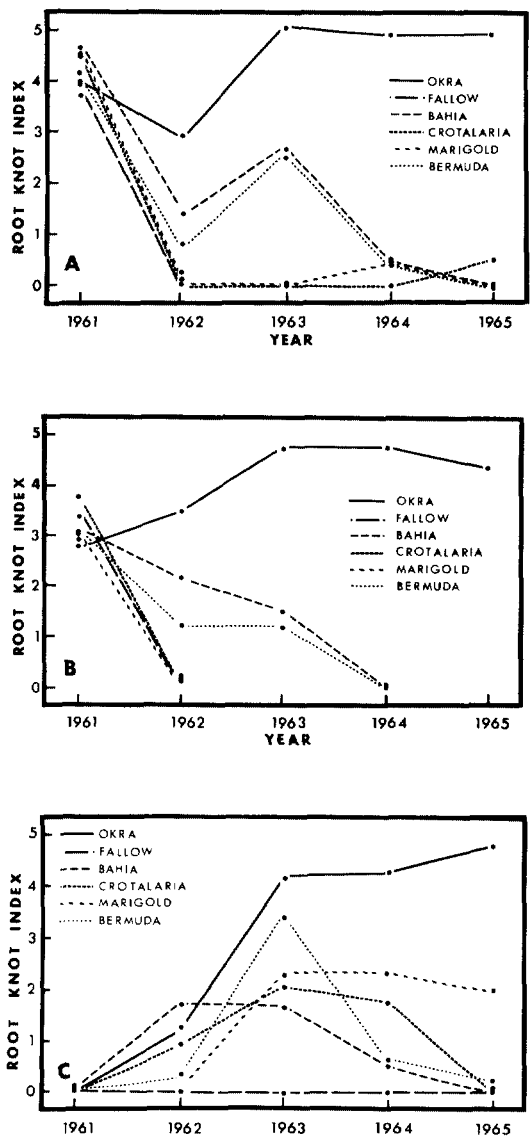

FIG. 1. Effects of selected crops and fallow on the population density of *Meloidogyne incognita*. **A**. Land previously in native pasture. **B**. Land previously cropped to okra. **C**. Land previously cropped to crotolaria. (Population line discontinued after the population reached zero for A, B, and not used until above zero for C).

Soil samples for nematode assay were taken in November of each year. Each sample, which consisted of twenty cores (2.1 × 20 cm) randomly collected from each plot, was mixed throughly, a 150-cc aliquant wet-sieved (20- and 325-mesh) and Baermann-pan-extracted for 48 h to separate the nematodes from the soil. In December of each year, a composite soil sample (3.75 liters) was removed from each subplot, placed in a greenhouse, and planted to tomato (*Lycopersicon esculentum* Mill.) for bioassay for *M. incognita*. After 6 wk, the tomato plants were rated for root galls. The plants were indexed on a 0 to 5 scale with 0 = no galls and 5 = maximum galling.

After 5 yr of crop growth, the plots were treated with nematicides and planted to tomato. Nematicides used were: aldicarb [2-methyl-2 (methylthio)propionaldehyde *O*-(methylcarbamoyl)oxime]; ethoprop (*O*,ethyl S,S-dipropyl phosphorodithioate); DBCP (1,2-dibromo-3-chloropropane); and EDB (ethylene dibromide). Aldicarb and ethoprop, granular formulations, were spread on the soil surface and incorporated into the top 10 cm of soil with a disk harrow. Liquid DBCP and EDB were injected 20 cm deep with chisels 20 cm apart. Tomato seeds were planted 2 wk after application of DBCP and EDB. Six weeks after planting, plant heights were recorded and roots were examined for galls.

RESULTS

Initial population densities of *M. incognita* varied with previous cropping history. Extremely high densities were found in land previously in native pasture, moderately high densities in land previously cropped to okra, and a very low densities in land previously cropped to crotalaria.

In land previously cropped to native pasture, 1 yr of fallow or crotalaria, 3 yr of marigold, or 4 yr of bahiagrass or bermudagrass reduced the *M. incognita* population below detectable levels (Fig. 1-A). A sharp increase in population density of *M. incognita* was noted on bahiagrass and bermudagrass the 3rd yr. Also, an increase in population density was noted after 3 yr of marigold and after 4 yr of crotalaria.

In land previously cropped to okra, *M. incognita* was reduced to below a detectable level after 2 yr of fallow, crotalaria, or marigold (Fig. 1-B). Bahiagrass and bermudagrass maintained a detectable population for 4 yr, and okra maintained an extremely high population density for 5 yr.

In land previously cropped to crotalaria, *M. incognita* was reduced to below a detectable level by 2 yr of fallow (Fig. 1-C). The population density increased on all crops for 3 yr and then decreased on all crops except okra and marigold which maintained a moderately high population density throughout the experiment. After 5 yr, bahiagrass and crotalaria reduced the population below a detectable level.

During the 5 yr of cropping systems, population densities of other important plant parasitic nematodes increased on certain crops. *Trichodorus christiei* increased on all cropping systems except fallow and crotalaria (Table 1). *Xiphinema americanum* was detected in all plots except fallow and increased substantially on crotalaria, bahiagrass, and bermudagrass. Population density of *P. brachyurus* increased significantly on crotalaria and to a lesser extent on bermudagrass. *Belonolaimus longicaudatus* was detected only where bermudagrass was grown.

Treatment with nematicides following 5 yr of cropping systems further reduced the *M. incognita* population and the degree of nematode control was influenced by pretreatment density. Treatment with EDB and DBCP was more effective where preplant density was low and reduced the density below a detectable level only where DBCP treatment followed 5 yr of bahiagrass (Table 2). Aldicarb reduced *M. incognita* below a detectable level following all cropping systems and ethoprop was similarly effective except where treatment followed okra.

Aldicarb and ethoprop also effectively reduced *T. christiei* and *X. americanum* populations (data not given). Their effectiveness was again influenced by pretreatment population densities. Plots in which crops had favored increases of both nematode species, also contained the highest population density after nematicide application.

The growth of tomato seedlings was influenced by both cropping system and chemical soil treatment. The height of plants was significantly greater following crotalaria, bermudagrass, or fallow than following okra

TABLE 1. Population densities of *Trichodorus christiei* (*T.c.*), *Xiphinema americanum* (*X.a.*), *Pratylenchus brachyurus* (*P.b.*), and *Belonolaimus longicaudatus* (*B.l.*) after 5 yr of selected cropping systems.

Cropping system	Nematodes/150 cc of soil			
	T. c.	*X. a.*	*P. b.*	*B. l.*
fallow	100	0	2	0
bahiagrass	490	98	4	0
crotalaria	49	752	116	0
bermudagrass	2,779	106	61	121
okra	996	4	12	0
marigold	1,964	24	1	0
LSD ($P = 0.05$)	1,654	NS	60	71

TABLE 2. Root knot indices of field-grown tomato transplants as influenced by four nematicidal treatments following six 5-yr cropping systems.

Nematicide treatment	Dosage/ha	Root-knot index of tomato plants on land previously cropped to —[a]						Nematicide treatment means
		Okra	'C' bermuda[b]	'P' bahia[c]	Crotalaria	Marigold	Fallow	
check	-	3.2	1.0	0.6	0.2	0.1	0.0	1.0
EDB	23 liters	1.6	0.1	0.0	0.1	0.1	0.0	0.4
DBCP	37 liters	1.0	0.1	0.3	0.3	0.2	0.0	0.4
ethoprop	11.2 kg	0.1	0.0	0.0	0.0	0.0	0.0	0.0
aldicarb	11.2 kg	0.0	0.0	0.0	0.0	0.0	0.0	0.0
cropping systems means			0.2	0.2	0.1	0.1	0.0	

LSD ($P = 0.05$) for
Nematicide treatment means = 0.18
Cropping systems means = 0.21
Individual comparions = 0.51

[a]0-5 scale with 0 = no galls and 5 = maximum galling.
[b]'C' bermuda = Coastal bermudagrass.
[c]'P' bahia = Pensacola bahiagrass.

TABLE 3. Height of field grown tomato transplants as influenced by nematicide treatment following 5-yr cropping systems.

Nematicide treatment	Dosage/ha	Height (cm) on land previously cropped to —						Nematicide treatment means
		Okra	'C' bermuda[a]	'P' bahia[b]	Crotalaria	Marigold	Fallow	
check	-	10.7	12.0	13.2	18.5	11.2	14.5	13.4
EDB	23 liters	11.9	15.7	14.5	20.1	14.5	15.7	15.4
DBCP	37 liters	9.7	9.7	11.7	18.0	10.4	13.0	12.1
ethoprop	11.2 kg	14.5	18.8	15.7	22.9	14.5	15.2	14.6
aldicarb	11.2 kg	17.3	24.1	20.8	23.4	19.6	19.6	20.8
cropping systems means		12.8	16.1	15.2	20.2	14.0	15.6	

LSD ($P = 0.05$) for
Nematicide treatment means = 3.1
Cropping systems means = 1.0

[a]'C' bermuda = Coastal bermudagrass.
[b]'P' bahia = Pensacola bahiagrass.

(Table 3). Nematicide treatments, except DBCP, further increased the height of transplants. Treatment with EDB significantly increased plant height when applied to plots in which crotalaria, marigold, or bahiagrass had grown. Aldicarb and ethoprop significantly increased plant height when applied to plots in which all cropping systems had grown.

DISCUSSION

These results with different cropping systems confirmed results from our previous studies (3, 4). However, *M. incognita* was not a factor in our previous studies. Crotalaria, marigold, and fallow were most effective in reducing the population density of *M. incognita*, but fallowing usually reduces organic-matter content of soil and causes low crop yields (6).

Our data emphasize the importance of preplant population density in designing a nematode control program. Where preplant population densities were low, a more rapid decline in density was obtained than when preplant densities were high. Also, nematicide treatments resulted in more consistent nematode control when applied to soil with low population densities, than when applied to soil with high population densities.

The different responses of *M. incognita* to different cropping systems indicate a variation in field populations of this nematode in the southeastern United States. Previous reports (3, 7) indicate that crotalaria, marigold, and bermudagrass are resistant to *M. incognita*. However, when these crops were grown on land previously cropped for 4 yr to crotalaria, *M. incognita* population density increased. We conclude that either a second species was present in low numbers and there was a shift in dominance of *Meloidogyne* spp. similar to that reported by Minton and Donnelly (8) and Sasser and Nusbaum (11), or there was development of a new biotype similar to that reported by Riggs and Winstead (10). Unfortunately we were not aware of this until the data were analyzed, and by then we had no material to determine whether the population contained a second species.

The differential response of *M. incognita* populations to different cropping systems and the ability of certain ectoparasitic nematodes to develop on root-knot resistant crops such as crotalaria, marigold, and bermudagrass, indicates a need for a combination of control methods for more efficient nematode control. In our test, soil treatment with aldicarb or ethoprop following 5 yr of cropping systems significantly reduced population density of all nematode species involved. Best nematode control and crop yields were obtained where both nematode-reducing cropping systems and nematicides were used. Similar results have been obtained in the control of root-knot nematodes on tobacco (5, 13).

LITERATURE CITED

1. BRODIE, B. B. 1968. Systemic pesticides for control of sting and stubby root nematodes on vegetables. Plant Dis. Rep. 52:19-23.
2. BRODIE, B. B., and P. D. DUKES. 1972. The relationship between tobacco yield and time of infection with Meloidogyne javanica. J. Nematol. 4:80-83.

3. BRODIE, B. B., J. M. GOOD, and C. A. JAWORSKI. 1970. Population dynamics of plant nematodes in cultivated soil: Effect of summer cover crops in old agricultural land. J. Nematol. 2:147-151.
4. BRODIE, B. B., J. M. GOOD, and C. A. JAWORSKI. 1970. Population dynamics of plant nematodes in cultivated soil: Effect of summer cover crops in newly cleared land. J. Nematol. 2:217-222.
5. DAULTON, R. A. C. 1963. The behavior and control of root-knot nematode, Meloidogyne javanica in tobacco as influenced by crop rotations and soil fumigation. Proc. Third World Tobacco Sci. Congr. 10 p.
6. GOOD, J. M. 1968. Relation of plant nematodes to soil management practices. Pages 113-138 *in* G. C. Smart, Jr., and V. G. Perry, eds. Tropical Nematology. University of Florida Press, Gainesville.
7. GOOD, J. M., N. A. MINTON, and C. A. JAWORSKI. 1965. Relative susceptibility of selected cover crops and Coastal bermudagrass to plant nematodes. Phytopathology 55:1026-1030.
8. MINTON, N. A., and E. D. DONNELLY. 1971. Reaction of field grown lespedeza to selected Meloidogyne spp. J. Nematol. 3:369-373.
9. PERRY, V. G., and A. J. NORDEN. 1963. Some effects of a cropping sequence on populations of certain plant nematodes. Proc. Soil Crop Sci. Soc. Fla. 23:116-121.
10. RIGGS, R. D., and N. N. WINSTEAD. 1959. Studies on resistance in tomato to root-knot nematodes and on the occurrence of pathogenic biotypes. Phytopathology 49:716-724.
11. SASSER, J. N., and C. J. NUSBAUM. 1955. Seasonal fluctuations and host specificity of root-knot nematode populations in two-year tobacco rotation plots. Phytopathology 45:540-545.
12. SUATMADJI, R. W. 1969. Studies on the effect of Tagetes species on plant parasitic nematodes. H. Veeman and N. V. Zonen, Wageningen. 132 p.
13. TODD, F. A. 1972. Telone C soil fumigant, an effective multipurpose disease control for tobacco. Down to Earth 26(4):5-11.