NEMATODE MANAGEMENT IN MINIMUM-TILL SOYBEAN WITH RESISTANT CULTIVARS, RYE ROTATION, AND ALDICARB†

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ABSTRACT

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Growth and yield of three soybean (*Glycine max*) cultivars planted minimum-till were studied for 3 years in relation to winter rye (*Secale cereale*) rotation, aldicarb treatment of soil, and population densities of *Meloidogyne incognita, Pratylenchus brachyurus,* and *Paratrichodorus minor.* Population densities of *M. incognita* second-stage juveniles (J2) were greater than 10 J2/cm^3 soil. Population densities of *P. brachyurus* and *P. minor* were less than 1 nematode/cm^3 soil. Rye did not affect the *M. incognita* J2 density measured in the soil in the spring, but root-gall indices of soybean following rye were lower than those following fallow. Root-gall indices of 'Coker 6738' were lower than for 'Coker 488' and 'Johnston'. Soybean yields of Coker 6738 were 133% and 174% greater than for Coker 488 and Johnston, respectively, in fallow, untreated plots. However, all cultivars maintained relatively high population densities of *M. incognita* J2 in the soil, indicating that high yields of Coker 6738 were due to tolerance as well as resistance to *M. incognita.* Aldicarb reduced nematode damage and increased yields of all cultivars. Winter rye increased the overall mean soybean yield by 17%. The maximum yield was obtained with aldicarb-treated Coker 6738 planted after winter rye.

Key words: control, *Glycine max, Meloidogyne incognita,* nematode management, *Paratrichodorus minor, Pratylenchus brachyurus, Secale cereale.*

RESUMEN

Minton, N. A. 1992. Manejo de nematodos en la soya de labranza mínima con cultivares resistentes, rotación con el centeno y aldicarb. Nematrópica 22:21–28.

El crecimiento y rendimiento de tres cultivares de la soya (*Glycines max*) plantados y cultivados con el método de labranza mínima fueron estudiados por 3 años con relación a, rotación con centeno de invierno, tratamiento del suelo con aldicarb, y las densidades poblacionales de *Meloidogyne incognita, Pratylenchus brachyurus* y *Paratrichodorus minor.* Densidades poblacionales de los segundos estadíos juveniles (J2) de *M. incognita* fueron superiores a 10 J2/cm^3 de suelo. Densidades poblacionales de *P. brachyurus* y *P. minor* fueron menores a 1 nematodo/cm^3 de suelo. El centeno no afectó la densidad de J2 de *M. incognita* medida en el suelo en la primavera, pero los índices de agallamiento de las raíces de la soya después del centeno fueron más bajos en comparación con el tratamiento de barbecho. Indices del agallamiento de las raíces de 'Coker 6738' fueron más bajos que los de 'Coker 488' y de 'Johnston'. Rendimientos de soya del Coker 6738 fueron 133% y 174% mayores que los del Coker 488 y el Johnston, respectivamente, en parcelas que habían sido en barbecho y no recibieron aldicarb. Sin embargo, todos los cultivares mantuvieron densidades poblacionales relativamente altas de J2 de *M.incognita* en el suelo, indicando que los altos rendimientos de Coker 6738 se debieron a una tolerancia como también a una resistencia a *M. incognita.* El aldicarb redujo el daño de nematodos e incrementó los rendimientos en todos los cultivares. El centeno de invierno incrementó el rendimiento medio de la soya en un 17%. El rendimiento más alto se obtuvo con Coker 6738 tratado con aldicarb y plantado después del centeno de invierno.

Palabras clave: control, *Glycine max,* manejo de nematodos, *Meloidogyne incognita, Paratrichodorus minor, Pratylenchus brachyurus, Secale cereale.*

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INTRODUCTION

Meloidogyne incognita (Kofoid & White) Chitwood is the most prevalent of several root-knot nematodes that parasitize soybean in the United States. It is endemic throughout most of the southeastern states where it can be devastating to soybean crops (10,15,19). High yield losses have also been reported in Argentina (17) and Brazil (3), other major soybean producing countries. Although yields of highly susceptible cultivars planted in infested soil may be reduced more than 50%, resistant cultivars (15,16,22) may produce 90% of a normal yield (19,23). The use of resistant cultivars has been the most important defense against *M. incognita*. However, in many fields where population densities are extremely high or where more than one nematode genus are present, it may be necessary to use resistant cultivars in conjunction with other means of control to obtain maximum yields (10,19).

Rotations are a primary tactic for reducing population levels of *Meloidogyne* spp. in many crops (30). Rotating soybean with crops that are immune or that have low susceptibility to *M. incognita* can increase soybean yields substantially (13,14). In Florida, yield losses of susceptible soybean cultivars were linearly related to the postharvest abundance of *M. incognita* J2 in the soil following the previous year's crop (14). In the southeastern United States, soybean is often planted after a winter crop of rye (*Secale cereale* L.) on which cattle have been grazed. There have been conflicting reports from greenhouse (5,7,25,26,29) and field (8,18,20,24, 27) studies regarding reproduction of *M. incognita* on rye. The effect of rye on soybean production in soil infested with *M. incognita* has not been adequately investigated. Fumigant and non-fumigant nematicides also reduce nematode damage to soybean (9,21). Fumigant nematicides are generally more effective. Combining two or more strategies, such as rye rotation and nematicide treatment, to control nematodes and other pests is often the most effective approach to pest management (4). The purpose of this research was to evaluate the effects of winter rye, soybean resistance to *M. incognita*, and aldicarb treatment of soil on soybean production in minimum-tilled soil infested with *M. incognita*.

MATERIALS AND METHODS

A 3-year experiment was conducted near Tifton, Georgia. In 1987, the experiment was in a field with Dothan soil (fine-loamy, siliceous, thermic Plinthic Paleudults), and in 1988 and 1989, it was in a field with Fuquay soil (loamy, siliceous, thermic Arenic Plinthic Paleudults). Both fields were planted to soybean the year preceding the experiment, and were infested with *Meloidogyne incognita* race 4, *Pratylenchus brachyurus* (Godfrey) Goodey, and *Paratrichodorus minor* (Colbran) Siddiqi.

The experimental design was a split-split plot with 'Wrens' abruzzi rye and undisturbed winter fallow comprising the whole plots; the nematicide, aldicarb (3.4 kg a.i./ha), and untreated control were subplots; and soybean cultivars, 'Coker 6738', 'Coker 488', and 'Johnston', were sub-subplots. These cultivars were used because of their range susceptibility to *M. incognita*. Coker 6738 is resistant and Coker 488 and Johnston are moderately resistant (1,15). Sub-plots were 6.1 m long and 3.7 m wide with four rows spaced 0.9 m apart. Treatments were replicated six times.

Rye plots were disked and planted 13 November 1986, 11 November 1987, and

28 November 1988. Fallowed plots were not disked; instead, soybean stalks were left on the soil surface and winter weeds were allowed to grow. The dominant weed in fallow plots was evening primrose (*Oenothera laciniata* Hill); weeds did not grow in rye plots. Rye and weeds were mowed with a rotary mower two or three times each year and the clippings were left on the plots. Rye and weeds were killed with glyphosate (1.1 kg a.i./ha) 1–2 weeks before planting soybean. Soybean was planted 20 May 1987, 12 May 1988, and 18 May 1989. Seeds were planted in the undisturbed rye stubble and in undisturbed fallow plots using a subsoiler, minimum-till planting unit. The subsoiler shank penetrated 36 cm deep, followed by a double-fluted coulter with attached press wheels that backfilled the subsoiler slit and prepared a 12-cm-wide seedbed. Aldicarb was applied in an 18-cm-wide band ahead of the planter and received no incorporation other than what occurred during the subsoiling-planting operation. Cultural practices and control of insects and weeds were as recommended by the Georgia Cooperative Extension Service. The experiment was irrigated as needed.

Soil samples were collected in the winter (February or March), spring (April or May), and fall (August, September, or November) each year for nematode assays. Ten 2.5-cm-diam cores of soil were collected from the 0–20 cm depth. Nematodes were extracted from 150 cm^3 of soil using a centrifugal-sugar flotation method (6) and were counted. Ten plants per plot were dug from the two outside rows of the sub-subplots and rated for root galling during September of each year. A scale of 1–10 was used with 1 = 1–10% and 10 = 90–100% of roots galled. Soybean yield and plant height data were obtained from the two inside rows of each sub-subplot 9 November 1987, 9 November 1988, and 13 November 1989.

Data were subjected to the appropriate analysis of variance for a split-split plot experimental design and Fisher's least significant differences were calculated (28). Unless otherwise stated all differences mentioned in the text are significant at $P \leq 0.05$.

RESULTS

Population densities of *M. incognita* J2 in the soil were high throughout the 3-year study. Overall, soil samples collected in the fall, winter, and spring yielded an average of 1 734, 731, and 454 J2/150 cm^3 soil, respectively. In the fall there were no significant differences in population densities among cultivars within aldicarb and control treatments; however, J2 population densities in the fall were higher in Coker 488 and Johnston plots than in Coker 6378 plots when averaged across winter rye, nematicide treatments, and years (Table 1). Aldicarb reduced average population densities of *M. incognita* J2 in plots planted to Coker 6738 and Johnston. The average population density did not differ statistically between rye and fallow plots in the fall or in the spring. In the winter, however, J2 density measured 955 J2/150 cm^3 soil in fallow plots and was significantly greater than the 507 J2/150 cm^3 soil in rye plots.

Roots of Coker 488 and Johnston cultivars were more severely galled than were roots of Coker 6738 in both aldicarb-treated and untreated plots (Table 1). Aldicarb reduced root-gall indices of all cultivars. The mean root-gall index was lower in plots planted after rye (5.6) than after fallow (6.7). There was an interaction (P = 0.002) for the root-gall index effect among cultivars, winter rye,

Table 1. Effects of soybean cultivars and at-plant application of aldicarb on root-gall indices and on numbers of *Meloidogyne incognita* juveniles in the soil near harvest.

Nematicide treatment	Cultivar			LSD ($P=0.05$)	Mean
	Coker 6738	Coker 488	Johnston		
	Juveniles/150 cm³ soil				
Aldicarb	1 175	1 668	1 485	NS[y]	1 442
Control	1 762	2 179	2 132	NS	2 024
LSD ($P=0.05$)	553	NS	553		391
Mean	1 469	1 924	1 808	339	
	Gall index[z]				
Aldicarb	3.3	5.2	5.4	0.4	4.6
Control	5.8	8.2	8.9	0.4	7.6
LSD ($P=0.05$)	0.5	0.5	0.5		0.3
Mean	4.5	6.7	7.1	0.2	

Data are for six replications averaged across winter rye and 3 years.
[y]NS = not significant.
[z]Gall index based on scale of 1–10: 1 = 0–10% and 10 = 90–100% of roots galled.

and aldicarb treatments. Root-gall indices of Coker 6738 were less than those of Coker 488 and Johnston in aldicarb-treated and untreated rye and fallow plots. Root-gall indices of Coker 488 were less than those of Johnston in both aldicarb-treated fallow plots and untreated rye plots; conversely, indices were greater for Coker 488 than for Johnston in aldicarb-treated rye plots.

Several significant differences in *P. brachyurus* densities were measured when averaged across 3 years of the study. In the fall, more *P. brachyurus* were recovered from soil in plots planted to Coker 6738 (56 nematodes/150 cm³ soil) than in plots planted to Coker 488 (14 nematodes/150 cm³ soil) and Johnston (22 nematodes/150 cm³ soil). The average number of *P. brachyurus* was significantly less in Coker 6738 plots treated with aldicarb (10 nematodes/150 cm³ soil) than in untreated plots (102 nematodes/150 cm³ soil). In the winter, average population densities of *P. brachyurus* were greater in fallow plots (27 nematodes/150 cm³ soil) than in rye plots (10 nematodes/150 cm³ soil. In the spring, similar differences were detected.

Population densities of *P. minor* in the fall were similar in all treatments and averaged 41 nematodes/150 cm³ soil across all treatments and years. The population density in the winter was about one-half of that in the fall and was not affected by treatment. By spring, the density of *P. minor* in rye plots had increased to 36 nematodes/150 cm³ soil and was significantly greater than in the fallow plots (21 nematodes/150 cm³ soil).

Aldicarb increased the average heights of the three soybean cultivars (Table 2). Within aldicarb-treated plots, Coker 6738 and Coker 488 were taller than Johnston. In control plots, Coker 6738 was taller than Coker 488 and Johnston.

The mean yields of Coker 6738 in the aldicarb-treated and untreated plots were greater than these of Coker 488 and

Table 2. Effects of aldicarb application on plant height and yield of three soybean cultivars grown on soil infested with *Meloidogyne incognita*.

Nematicide treatment	Cultivar			LSD ($P = 0.05$)	Mean
	Coker 6738	Coker 488	Johnston		
		Height (cm)			
Aldicarb	80	81	74	5	78
Control	68	63	54	5	62
LSD ($P = 0.05$)	5	5	5		2
Mean	74	72	64	3	
		Yield (kg/ha)			
Aldicarb	2 893	1 953	1 998	196	2 281
Control	2 036	1 004	775	196	1 272
LSD ($P = 0.05$)	240	240	240		177
Mean	2 465	1 479	1 387	138	

Data are for six replications averaged across winter rye and 3 years.

Johnston (Table 2). Aldicarb increased yields of all cultivars. Winter rye rotation increased soybean yield by 285 kg/ha (17.4%) when averaged across cultivars, nematicide treatments, and years. There were no interactions among treatments. The mean yield across all treatments and years was negatively correlated with root-gall index ($P = 0.0001$) ($r = -0.73$) and with the population density of *M. incognita* J2 in the fall ($P = 0.0001$) ($r = -0.32$). There was a positive correlation ($P = 0.0001$) of yield with plant height ($r = +0.52$).

DISCUSSION

Pratylenchus brachyurus and *P. minor* generally are not considered serious pathogens of soybean. The relatively low population densities of these two nematodes in this experiment suggest that they had little effect on yield. Greater densities of *P. brachyurus* in Coker 6738 than in Coker 488 and Johnston plots may have resulted from less root damage by *M. incognita* on Coker 6738. Lower population density of *P. brachyurus* in the soil in rye than in fallow plots during the winter and spring may have been the result of nematode penetration of the rye roots. No attempt was made to recover *P. brachyurus* from roots. Alternatively, weeds in fallow plots could have been better hosts than rye for *P. brachyurus*. The greater population density of *P. minor* in rye than in fallow plots with winter weeds suggests that *P. minor* reproduced best on rye.

The greater number of *M. incognita* J2 in fallow than in rye plots in the winter, and the greater root-gall indices for soybean in fallow than rye plots, suggest that rye rotation reduced nematode populations and thereby increased yield of the subsequent soybean crop. The yield of continuous soybean in Florida (11) was negatively correlated with the number of *M. incognita* J2 in the soil in the spring. In an earlier study at Tifton, Georgia (20), however, differences between population densities of *M. incognita* J2 in rye and fallow plots in the spring had little effect on juvenile population densities in the fall, on soybean root-gall indices, or on soybean yields.

A lower root-gall index for Coker 6738 than for Coker 488 and Johnston corroborates results of others (1,15). The high yield of Coker 6738 and low yields of Coker 488 and Johnston are congruent with reported differences in susceptibility of the three cultivars to *M. incognita*. Some yield differences among the three cultivars may be inherent, but all cultivars produced similarly high yields in performance tests in other soils free of nematodes near Tifton (1,2). Although root-gall indices differed among cultivars in both aldicarb and control plots, the numbers of *M. incognita* J2 in the soil in the fall did not differ significantly. Similar results have been obtained in previous studies where soybean cultivars considered to be moderately resistant to *M. incognita* supported almost as many nematodes as more susceptible cultivars (9,19). Therefore, tolerance as well as resistance to *M. incognita* may contribute appreciably to soybean yield. The greater yield of Coker 6738 than Coker 488 and Johnston is indicative of the value of combined resistance and tolerance for managing *M. incognita* problems in soybean.

The relative values of nematode resistance, winter rye, and aldicarb treatment in minimum-till soybean production in *M. incognita* infested soil were compared in these experiments (Fig. 1). The resistant cultivar Coker 6738 yielded 174% more than Johnston and 133% more than Coker 488 in fallow, untreated plots. The maximum yield potential of Coker 6738, however, was not attained when compared to plots rotated with rye and treated with aldicarb. Although the yield of Coker 6738 was not increased significantly solely by rotating with rye, its yield was increased 55% when it was rotated with rye and also treated with al-

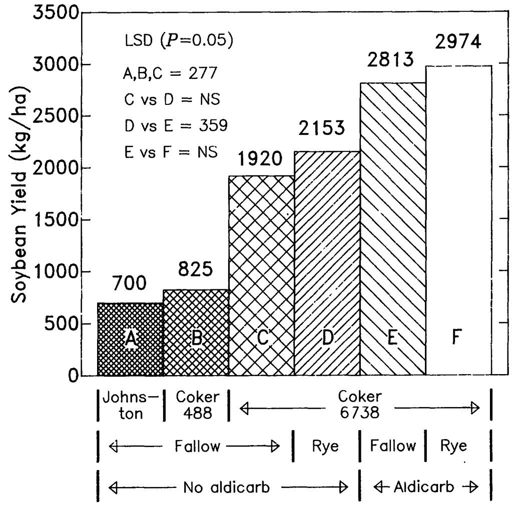

Fig. 1 Three-year mean soybean yield as related to soybean cultivar, winter rye, and nematicide treatments.

dicarb. Thus, rye rotation and aldicarb treatment were beneficial, but their contributions were small compared to genetic resistance to *M. incognita*. These results emphasize the importance of planting resistant soybean cultivars in *M. incognita* infested soil and confirm the need for soybean breeders to incorporate greater resistance into new cultivars. In fields heavily infested with *M. incognita*, rotating soybean with rye planted for grazing cattle and treating with a nematicide may be advantageous in some instances.

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LITERATURE CITED

1. ANONYMOUS. 1984. Pp. 4–32 *in* M. J. Cordonnier, J. L. Day, C. D. Fisher, and W. T. Pettigrew, eds. 1983 Field Crops Performance Tests: Soybeans, Peanuts, Sorghum, Cotton, Tobacco, Sunflowers, and Summer Annual

Forages. University of Georgia Research Report 447. Athens, Georgia, U.S.A.

2. ANONYMOUS. 1988. Soybeans. Pp. 2–26 *in* P. L. Raymer, J. L. Day, C. D. Fisher, and R. H. Hyerdahl, eds. 1987 Field Crops Performance Tests: Soybeans, Peanuts, Cotton, Tobacco, Sorghum, Summer Annual Forages, and Sunflowers. University of Georgia Research Report 551. Athens, Georgia, U.S.A.
3. ANTONIO, H. 1988. Avaliação das perdas causadas por *Meloidogyne incognita* raça 4 no cultivar Br 4 de Soja. Nematologica Brasileira 12:29–34.
4. BIRD, G. W. 1987. Role of nematology in integrated pest management programs. Pp. 114–121 *in* J. A. Veech and D. W. Dickson, eds. Vistas on Nematology. Society of Nematologists, Inc.: Hyattsville, Maryland, U.S.A.
5. CRITTENDEN, H. W. 1961. Studies of the host range of *Meloidogyne incognita acrita*. Plant Disease Reporter 45:190–191.
6. JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from the soil. Plant Disease Reporter 48:692.
7. JOHNSON, A. W., and R. E. MOTSINGER. 1989. Suitability of small grains as hosts of *Meloidogyne* spp. Supplement to the Journal of Nematology 21:650–653.
8. JOHNSON, A. W., and R. E. MOTSINGER. 1990. Effects of planting date, small grain crop destruction, fallow, and soil temperature on the management of *Meloidogyne incognita*. Journal of Nematology 22:348–355.
9. KINLOCH, R. A. 1974. Response of soybean cultivars to nematicidal treatments of soil infested with *Meloidogyne incognita*. Journal of Nematology 6:7–11.
10. KINLOCH, R. A. 1980. The control of nematodes injurious to soybean. Nematropica 10:141–153.
11. KINLOCH, R. A. 1982. The relationship between soil populations of *Meloidogyne incognita* and yield reduction of soybean in the Coastal Plain. Journal of Nematology 14:162–167.
12. KINLOCH, R. A. 1983. Influence of maize rotations on the yield of soybean grown in *Meloidogyne incognita* infested soil. Journal of Nematology 15:398–405.
13. KINLOCH, R. A. 1986. Soybean and maize cropping models for the management of *Meloidogyne incognita* in the Coastal Plain. Journal of Nematology 18:451–458.
14. KINLOCH, R. A., and T. D. HEWITT. 1984. Economic analysis of monocultured and maize-rotated soybean crops grown on southern root-knot nematode infested soil. Proceedings of the Soil Crop Science Society of Florida. 43:172–174.
15. KINLOCH, R. A., C. K. HIEBSCH, and H. A. PEACOCK. 1987. Evaluation of soybean cultivars for production in *Meloidogyne incognita* infested soil. Annals of Applied Nematology (Supplement to Volume 19 of the Journal of Nematology) 1:32–34.
16. KINLOCH, R. A., and K. HINSON. 1973. The Florida Program for evaluating soybean (*Glycine max* (L.) Merr.) genotypes for susceptibility to root-knot nematode disease. Proceedings of the Soil and Crop Science Society of Florida. 32:173–176.
17. MARCH, G. J., J. GARCIA, J. A. ORNAGHI, and J. E. BEVIACQUA. 1990. Distribution and damage of *Meloidogyne* spp. in soybean in Córdoba, Argentina. Nematropica 20:11.
18. McSORLEY, R., and D. W. DICKSON. 1989. Nematode population density increase on cover crops of rye and vetch. Nematologica 19:39–51.
19. MINTON, N. A., and M. B. PARKER. 1974. Yields of six soybean cultivars following fumigation of soil infested with root-knot nematodes. Phytopathology 64:219–221.
20. MINTON, N. A., and M. B. PARKER. 1987. Root-knot nematode management and yield of soybean as affected by winter cover crops, tillage systems, and nematicides. Journal of Nematology 19:38–43.
21. MINTON, N. A., M. B. PARKER, O. L. BROOKS, and C. E. PERRY. 1976. Evaluation of nematicides for control of nematodes in soybeans. University of Georgia Agricultural Experiment Station Research Bulletin 189. Athens, Georgia, U.S.A. 19 pp.
22. MINTON, N. A., M. B. PARKER, and R. A. FLOWERS. 1975. Response of soybean cultivars to *Meloidogyne incognita* and to the combined effects of *M. arenaria* and *Sclerotium rolfsii*. Plant Disease Reporter 59:920–923.
23. MINTON, N. A., M. B. PARKER, and B. G. MULLINIX, Jr. 1978. Effects of cultivars, subsoiling, and fumigation on soybean yields and *Meloidogyne incognita* populations. Journal of Nematology 10:43–47.
24. OPPERMAN, C. H., J. R. RICH, and R. A. DUNN. 1988. Reproduction of three root-knot nematodes on winter small grain crops. Plant Disease 72:869–871.
25. PEDERSEN, J. F., and R. RODRIGUEZ-KABANA. 1987. Nematode response to cool

season annual graminaceous species and cultivars. Annals of Applied Nematology (Supplement to Volume 19 of the Journal of Nematology) 1:116–118.

26. SASSER, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (*Meloidogyne* spp.). Bulletin of the Maryland Agricultural Experiment Station A-77. College Park, Maryland, U.S.A. 31 pp.

27. SMITTLE, D. A., and A. W. JOHNSON. 1982. Effects of management practices on *Meloidogyne incognita* and snapbean yield. Journal of Nematology 14:63–68.

28. STEEL, R. G. D., and J. H. TORRIE. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc.: New York.

29. THOMASON, I. J. 1962. Reaction of cereals and sudan grass to *Meloidogyne* spp. and the reaction of soil temperature to *M. javanica* populations. Phytopathology 52:787–791.

30. TRIVEDI, P. C., and K. R. BARKER. 1986. Management of nematodes by cultural practices. Nematologica 16:213–236.

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