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Rotations of Soybean with Tropical Corn and Sorghum for the Management of Nematodes

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Abstract: The relative efficacy of rotations of soybean with sorghum and tropical corn for nematode management was studied for 2 years in a field infested with root-knot (*Meloidogyne arenaria*) and soybean cyst (*Heterodera glycines*, race 14) nematodes. Corn, sorghum, and soybean cv. Kirby were planted in 1989, and in 1990 the same areas were planted with seven soybean cultivars with and without at-plant application of aldicarb. Corn and sorghum did not support *H. glycines*, but significant juvenile populations of the nematode in soil were associated with Kirby soybean. Numbers of *H. glycines* and *M. arenaria* juveniles in 1990 depended on cultivar and cropping system but were little affected by nematicide treatment. Lowest numbers of *H. glycines* juveniles were associated with Leflore soybean and the corn–soybean rotation. Numbers of *M. arenaria* juveniles were highest with Leflore and lowest with Braxton and Brim soybean. The sorghum–soybean rotation resulted in slightly higher numbers of *M. arenaria* juvenile populations than soybean monoculture or the corn–soybean rotation. Aldicarb increased yields of some cultivars, but its use was not justified economically. Yields of all cultivars were from 19–287% higher in rotation systems than in monoculture.
Key words: aldicarb, control, corn, cropping system, cultural practice, *Glycine max*, *Heterodera glycines*, *Meloidogyne arenaria*, nematicide, nematode, pest management, root-knot nematode, rotation, sorghum, *Sorghum bicolor*, soybean, soybean cyst nematode, *Zea mays*.

Damage from nematodes is one of the principal yield-limiting factors in the production of soybean (*Glycine max* (L.) Merr.) in the southeastern part of the United States and other areas of the world (6,16,23). Root-knot nematodes (*Meloidogyne* spp.) and the soybean cyst nematode (*Heterodera glycines* Ichinohe) are the most economically important nematode species for the crop (5,21–23). In Alabama and other areas of the southeastern United States, species of root-knot nematodes and the cyst nematode occur frequently together in the same field. These coincident infestations can lead to problems so severe that soybean production is not possible without adequate management of the nematodes, even with resistant cultivars. Traditionally, management of nematode problems in soybean has been based on use of resistant cultivars, rotation with nonhost crops or with crops that are less suitable hosts than soybean (6,25), and the use of nematicides (6). The removal of inexpensive and efficacious fumigant nematicides (DBCP, EDB) has left producers with very few nematicides for use with soybean (2,6). Nematicides currently available are more expensive that the former fumigants, and their relative efficacy depends on soybean cultivars, on the nematode species present, and on the level of infestation of the fields to be treated (6,9,14). There are a number of soybean cultivars with combined resistance to several *Meloidogyne* spp. and several races of *H. glycines* (6,26). Yields of these cultivars can be improved by nematicide applications or the use of other nematode management techniques (7,15, 26–28). The use of rotations for the management of nematode problems has been particularly effective in fields with coincident infestations of root-knot and cyst nematodes. Rotations of soybean with bahiagrass (*Paspalum notatum* Flügge; 18), corn (*Zea mays* L.; 3,4,29), and other crops (11,12,19,20) have improved yields of soybean cultivars with a wide range of resistance to nematodes. The use of rotations, however, is limited by the different production constraints faced by individual

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producers. There is a continuing need to assess the value of additional rotation systems to provide producers with additional options to fit individual production requirements. Tropical corn can be planted much later than standard field corn in Alabama and other southern states of the United States. This property may permit double cropping with wheat (*Triticum* spp.) or with soybean, which may be economically attractive. This paper presents results of a study designed to assess the value of tropical corn and grain sorghum (*Sorghum bicolor* (L.) Moench) for the management of nematode problems on soybean in south Alabama.

Materials and Methods

The value of tropical corn cv. Pioneer hybrid X304C and of sorghum cv. Pioneer hybrid 8333 for the management of nematode problems in soybean was studied in a field near Elberta, Baldwin County, in southeast Alabama. The field had been in soybean following ryegrass (*Lolium* spp.) or wheat (*Triticum aestivum* L.) winter cover crops for the preceding 6 years and was infested with the cyst nematode *Heterodera glycines* race 14 and the root-knot nematode *Meloidogyne arenaria* (Neal) Chitwood race 2. The soil was a sandy loam with a pH of 6.2, organic matter content less than 1.0% (w/w), and cation exchange capacity less than 10 meq/100 g soil. In 1989 the field was divided into six rectangular sections each 29 × 100 m. Two sections were planted with soybean cv. Kirby, two with sorghum, and two with tropical corn. The sections were planted to have a completely randomized design with respect to crops. No yield data were obtained for corn, sorghum, or soybean in 1989.

The field was left fallow during the winter of 1989–90, after which each section was divided into eight blocks, each 6 m long and 36 rows wide. The row width was 0.81 m, and blocks were separated by alleys 6 m long. Blocks were divided into 14 two-row plots with four border rows of Kirby soybean on each side of the blocks. Plots were planted with seven soybean cultivars so that in every block and for each cultivar one plot was treated with aldicarb and one was not. Soybean cultivars are listed with their response as hosts for the nematodes (Table 1). Aldicarb was applied at-plant at 18 g a.i./100 m of row in a 20-cm-wide band with the seed furrow in the middle. The granules were incorporated 2–3 cm into the soil by means of spring-activated tines attached to the planting equipment. Treatments were arranged in a randomized complete block design. Overall, the experimental design was a three-level factorial, with three previous crops × seven cultivars × two nematicide levels.

Table 1. Relative resistance and susceptibility of soybean cultivars to root-knot (*Meloidogyne arenaria* race 2) and cyst (*Heterodera glycines* race 14) nematodes.

Cultivar	Maturity group	*M. arenaria*	*H. glycines*
Braxton	VII	Resistant	Susceptible
Brim	VI	Susceptible	Susceptible
Bryan	VI	Resistant	Susceptible
Kirby	VIII	Resistant	Susceptible
Leflore	VI	Susceptible	Resistant
Stonewall	VII	Susceptible	Susceptible
Thomas	VII	Susceptible	Susceptible

Cultural practices and control of insects and weeds for all crops were according to recommendations for the area (1,2). Soybean yields were obtained at maturity of the crop by harvesting the entire plot area.

Soil samples for nematode analysis were collected in both years one month before soybean harvest to coincide with the period of maximal numbers of *Meloidogyne* juveniles in soil (17). In 1989 eight samples were collected from each section. A sample consisted of 20 to 25 cores taken diagonally across the areas where the blocks were to be positioned in 1990. Cores 2.5 cm diam × 20–25 cm deep were collected from the root zone of the plants. The cores from each sample were composited and a 100-cm^3 subsample was used to determine nematode numbers using the "salad bowl" incubation technique (13). In 1990, soil samples were collected from each plot by taking 15 to 20 cores from the two rows

TABLE 2. End-of-season juvenile populations of *Heterodera glycines* in soil from a rotation experiment with seven soybean cultivars with and without nematicide treatment and following sorghum, tropical corn, or soybean.

Cultivar	Juveniles per 100 cm³ soil					
	Soybean–soybean		Sorghum–soybean		Corn–soybean	
	Untreated	Treated†	Untreated	Treated†	Untreated	Treated†
Braxton	139	202	184	142	127	97
Brim	78	46	140	162	36	28
Bryan	116	108	167	59	69	12
Kirby	107	61	178	100	51	28
Leflore	17	3	7	3	3	3
Stonewall	83	60	53	59	21	19
Thomas	73	56	69	52	43	8

Fisher's least significant difference ($P = 0.05$) for comparisons between any two means within columns is 74, for comparing any two means across nematicide treatments within cropping systems is 97, and for comparing any two means within nematicide treatments across cropping systems is 108 juveniles/100 cm³ soil.

† Aldicarb treatment was at-plant at 18 g a.i./100 m row in a 20-cm-wide band with the seed furrow in the middle of the band.

through the center of the plots at equal spacings. The cores from a plot were composited and nematodes were extracted as described for the 1989 samples.

All data were analyzed following standard procedures for analysis of variance for a three-way factorial design (8,24). Fisher's least significant differences (FLSD) were calculated when F values were significant and are included in the tables of results. Unless otherwise stated, all differences referred to in the text were significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

At the end of 1989, juveniles of *M. arenaria* were lower ($P \leq 0.05$, FLSD = 112) in sections with sorghum (6/100 cm³ soil) or tropical corn (231/100 cm³ soil) than in sections following soybean (451/100 cm³ soil). Numbers of *H. glycines* were very low ($P \leq 0.05$, FLSD = 45) in sections with sorghum (4/100 cm³ soil) and corn (0/100 cm³ soil) compared to soybean (64/100 cm³).

Numbers of *H. glycines* juveniles in 1990 were influenced by soybean cultivar and rotation system (Table 2). Nematicide treatments and previous crops interacted significantly with cultivars on numbers of *H. glycines* juveniles. The lowest populations of *H. glycines* juveniles were in plots with Leflore and the highest populations in those with Braxton, Bryan, and Kirby in the monoculture and sorghum–soybean cropping systems. Numbers of *H. glycines* were lower in the corn–soybean rotation than in the soybean–soybean system. In most instances (Table 2), application of aldicarb had no effect on numbers of *H. glycines* juveniles.

Numbers of *M. arenaria* juveniles were larger than those of *H. glycines* (Table 3). Population size of *M. arenaria* juveniles depended on soybean cultivar and on cropping system; however, nematicide application had no suppressive effect on end-of-season population of the nematode. Cultivar effects and nematicide treatment effects on *M. arenaria* juvenile populations were dependent upon previous crop, but other interactions were not significant.

Nematicide application resulted in increased yields for some cultivars (Table 4), and magnitude of the response was also dependent on cropping system. Other interactions were not significant. Thus, aldicarb increased yield of Bryan in the monoculture system but not in the two rotations, but with Brim the nematicide increased yields in the rotation systems but not in monoculture. Yields of Kirby, Leflore, Stonewall, and Thomas were improved by aldicarb in all three cropping systems. Braxton yields were not influenced by aldicarb in the monoculture or

TABLE 3. End-of-season juvenile populations of *Meloidogyne arenaria* in soil from a rotation experiment with seven soybean cultivars with and without nematicide treatment and following sorghum, tropical corn, or soybean.

	Juveniles per 100 cm³ soil					
	Soybean–soybean		Sorghum–soybean		Corn–soybean	
Cultivar	Untreated	Treated†	Untreated	Treated†	Untreated	Treated†
Braxton	392	365	321	492	492	377
Brim	287	323	500	594	471	322
Bryan	510	422	454	536	540	353
Kirby	544	651	661	626	489	489
Leflore	681	707	799	751	605	564
Stonewall	403	457	488	617	524	451
Thomas	545	642	722	703	564	700

Fisher's least significant difference ($P = 0.05$) for comparisons between any two means within columns or across nematicide treatments within cropping systems is 149, and for comparing any two means within nematicide treatments across cropping systems is 216 juveniles/100 cm³ soil.

† Aldicarb treatment was at-plant at 18 g a.i./100 m row in a 20-cm-wide band with the seed furrow in the middle of the band.

the corn–soybean rotation but were improved by the nematicide in the sorghum–soybean system.

Yields of all cultivars were higher in the rotation systems than in monoculture. The overall average yields for all cultivars in monoculture, corn–soybean, and sorghum–soybean systems were 717, 1,258, and 1,323 kg/ha, respectively. The magnitude of the yield response to the rotations varied widely among cultivars. Thus, although yield improvements in response to the rotations relative to the monoculture for Bryan, Kirby, and Leflore varied from 20 to 62% (Table 5), those for the other cultivars ranged from 170 to 287%.

Results indicate that rotation with sorghum or with tropical corn can be used effectively to increase soybean yields in fields with concomitant infestations of root-knot and cyst nematodes. In previous studies in the same area of the present experiment, we showed that rotations with standard field corn (29) or sorghum (19) can be used to increase soybean yields. In those studies, as in the present one, the relative efficacy of the rotations depended on soybean cultivars used. Cultivars with little or no resistance or susceptible to the nematodes gave the best response to rotation. Cultivars Kirby, Bryan, and Leflore with resistance to either *M. arenaria* or *H.*

TABLE 4. Seed yields for seven soybean cultivars with and without nematicide treatment and following tropical corn, sorghum, or soybean.

	Soybean yield (kg/ha)					
	Soybean–soybean		Sorghum–soybean		Corn–soybean	
Cultivar	Untreated	Treated†	Untreated	Treated†	Untreated	Treated†
Braxton	289	397	827	1,251	988	1,130
Brim	235	390	666	1,130	753	1,029
Bryan	1,244	1,526	1,715	1,822	1,580	1,735
Kirby	1,103	1,419	1,674	1,950	1,567	1,876
Leflore	713	1,224	1,358	1,782	1,224	1,634
Stonewall	195	538	975	1,190	632	1,150
Thomas	262	524	914	1,278	914	1,210

Fisher's least significant difference ($P = 0.05$) for comparisons between any two means within columns or across nematicide treatments within cropping systems is 207, and for comparing any two means within nematicide treatments across cropping systems is 369 kg/ha.

† Aldicarb treatment was at-plant at 18 g a.i./100 m row in a 20-cm-wide band with the seed furrow in the middle of the band.

TABLE 5. Soybean yield averaged across nematicide treatments for seven cultivars and three cropping systems in a field infested with *Meloidogyne arenaria* and *Heterodera glycines* (race 14) near Elberta, Baldwin County, Alabama.

Cultivar	Soybean–soybean	Sorghum–soybean		Corn–soybean	
	Yield (kg/ha)	Yield (kg/ha)	Percentage increase†	Yield (kg/ha)	Percentage increase†
Braxton	343	1,039	203	1,059	209
Brim	312	898	287	891	285
Bryan	1,385	1,768	28	1,658	20
Kirby	1,261	1,812	44	1,722	37
Leflore	969	1,570	62	1,429	48
Stonewall	367	1,083	195	891	143
Thomas	393	1,096	179	1,062	170

Fisher's least significant difference ($P = 0.05$) for comparisons between any two means for yield within columns is 147, and for comparing any two means across cropping systems is 262 kg/ha.
† Percentage increase over yield in soybean–soybean system for this cultivar.

glycines race 14 had highest overall yields. Braxton was the exception to this trend. In 1989 tropical corn did not suppress *M. arenaria* populations to the degree that sorghum did. This may account for the slight advantage in soybean yield response observed for the sorghum rotation over the tropical corn rotation. There is considerable variation in the response of corn hybrids and inbred lines to *Meloidogyne* spp. (10). It may be possible to select tropical corn cultivars resistant or nonhost to *M. arenaria* and thus improve the efficacy of a tropical corn–soybean rotation. It should be noted, however, that in the present study, as in previous ones (19,29), rotations of soybean with graminaceous crops have not reduced root-knot nor cyst nematode populations to levels below which the nematodes ceased to be problematic for soybean production. The exponential nature of root-knot nematode population development (17) indicates that only a few surviving juveniles from season to season are sufficient to regenerate populations to high levels. Therefore, rotations must be considered as permanent components of the soybean production system when used to manage severe nematode problems.

Results from the present study also agree with previous rotation studies that indicate the yield response obtained from nematicide applications does not justify economically their use with either resistant or susceptible soybean cultivars (19–21,29). The cost of the nematicide treatment in this study was estimated at U.S.$49/ha, which requires a yield response of 549 kg/ha with soybean prices set at U.S.$0.23/kg ($6.00/bushel).

In conclusion, our results indicate that tropical corn–soybean and sorghum–soybean rotations are useful to manage nematode problems. Improvements in nematode and insect resistance in tropical corn cultivars may make this crop attractive for rotations or even for double-crop production systems in the southeastern United States.

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