# YIELD OF SORGHUM AND SOYBEAN, GROWN AS MONOCROPS AND IN ROTATION, AS AFFECTED BY INSECTICIDE AND NEMATICIDE APPLICATIONS[†]

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## ABSTRACT

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A study was conducted over 3 years to determine the yield of sorghum [*Sorghum bicolor* (L.) Moench] and soybean [*Glycine max* (L.) Merr.] grown as monocrops and in rotation on different soil types treated with insecticides or nematicides at planting in consecutive growing seasons in Mississippi, U.S.A. Cyst, stunt, lesion, and spiral nematodes were consistently detected on different soil types during all growing seasons. When the reproductive capability of these 4 nematodes was assessed, location was a significant main effect reflecting responses to the different soil types. At a specific location, there were differences in nematode reproduction rates between rotations. Crop rotation significantly increased yield of both sorghum and soybean. An alternate year rotation resulted in yield advantages over monocropping. The highest yields for both sorghum and soybean were attained on sandy loam soil. Insecticide or nematicide treatment at planting resulted in little positive yield responses for either crop grown in rotation or monocropped. On soils in the Coastal Plain and Prairie land resource areas of Mississippi, rotation of sorghum and soybean in alternate years provides yield advantages that cannot be achieved with insecticide or nematicide application to these crops in rotation or monocropped.

*Key words:* aldicarb, cyst nematode, ethoprop, *Glycine max*, *Helicotylenchus*, *Heterodera glycines*, insecticide, lesion nematode, nematicide, phorate, *Pratylenchus zeae*, *Quinisulcius acutus*, rotation, sorghum, *Sorghum bicolor*, soybean, spiral nematode, stunt nematode, terbufos, *Tylenchorhynchus* spp.

## RESUMEN

Trevathan, L. E. y J. T. Robbins. 1995. Producción de sorgo y soya como monocultivos y en rotación, bajo el efecto de aplicaciones de insecticidas y nematicidas. Nematrópica 25:125-134.

Este estudio de tres años se realizó para determinar la producción de sorgo (*Sorghum bicolor* L. Moench) y Soya (*Glycine max* L. Merr) como monocultivos y en rotación en diferentes tipos de suelo tratados con insecticidas ó nematicidas a la siembra en estaciones consecutivas de crecimiento en el Mississippi. Cuatro diferentes tipos de nematodes enquistados y estiletados se detectaron consistentemente en los distintos tipos de suelo en todas las estaciones de crecimiento. La localidad constituyó el principal efecto cuando la capacidad reproductiva de los cuatro tipos de nematodos se midió, reflejando respuestas en función del tipo de suelo. Para una determinada localidad, hubo diferencias en las tasas reproductivas entre las rotaciones. Las rotaciones de cultivo tuvieron efectos significativos sobre las producción tanto en el sorgo como en la soya. Un año alternado en la rotación dió ventajas en las producción comparando con la siembra continua de monocultivo. En ambos cultivos los máximos rendimientos se lograron en suelos limo arenosos. Los tratamientos con insecticidas o nematici-

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das a la siembra, no dieron resultados positivos en la producción en ambos cultivos en la rotación ni en el monocultivo. En suelos, de las planicies costeras ó de las praderas del Mississippi, la rotación de sorgo y soya en años alternados dieron ventajas en la producción que no se lograron con las aplicaciones de nematicidas e insecticidas en ambos cultivos con los dos sistemas de manejo.

*Palabras clave*: aldicarb, nematodo enquistado, ethoprop, *Glycine max, Helicotylenchus, Heterodera glycines*, insecticida, nematodo lesionador, nematicida, phorato, *Pratylenchus zeae, Quinisulcius acutus*, rotación, sorgo, *Sorghum bicolor*, soya, nematodo espiralado, nematodo "stunts", terbufos, *Tylenchorhynchus* spp.

## INTRODUCTION

Plant-parasitic nematodes are significant soilborne pests that can be managed by crop rotation. Other management strategies for these pests include using nematode resistant germplasm and the application of nematicides. However, the ability of nematodes to adapt genetically due to selection pressure imposed by plant resistance requires the use of alternative tactics. Rotation with nonhost crops and multiple cropping systems have been recommended to manage certain nematode populations (6,21,22). Where multiple cropping has been successful, control achieved due to the presence of more than one crop in rotation can actually be a secondary effect. One example is the planting of soybean [*Glycine max* (L.) Merr.] following wheat (*Triticum aestivum* L.). Initial populations of the soybean cyst nematode (*Heterodera glycines* Ichinohe) were reduced; however, this was a result of delayed soybean planting (13).

Soybean is a leading agricultural commodity in the southern United States. In Mississippi alone, soybean plantings increased from less than 40 500 ha in 1944 to approximately 729 000 ha in 1992. Soybean is currently grown in rotation with maize (*Zea mays* L.) and sorghum [*Sorghum bicolor* (L.) Moench] and often double-cropped with wheat. Alternating a leguminous and a gramineous crop is beneficial in a number of ways, including nitrogen fixation by legumes and the reduction of soilborne pests detrimental to both crops.

The soybean cyst nematode is one of the more serious nematode pests of soybean in the United States (20), and rotation with nonhosts is recommended in Mississippi. However, gramineous crops used in multiple cropping systems often serve as hosts for nematode species that are also able to reproduce on soybean. Recent surveys have shown that crop rotation does not always reduce certain plant-parasitic nematode populations below economic injury levels (19).

Nematode samples from the rhizosphere of symptomatic sorghum root systems in Mississippi have yielded high numbers of lesion and stunt nematodes (4). Previous reports confirm that warm-season forages and grains, including sorghum and millet, are hosts of nematodes (11). Also, it has been demonstrated that the growth of some cool-season grasses is significantly increased by soil fumigation, which reduces nematode populations (8). Fumigants show efficacy toward a wide spectrum of soilborne pests. Yield response to soil fumigation is a complex phenomenon and may result from effects other than reduced nematode populations (10,18). The use of specific nematicidal materials for seed treatment in grasses and small grains, however, provided effective control of lance and stunt nematodes (9). Maximum yield of peanut has been obtained under conventional tillage when nematicides were applied (16).

The objectives of this research were to determine nematode populations and yield of monocropped and rotated sorghum and soybean on different soil types treated with insecticides or nematicides at planting.

## MATERIALS AND METHODS

Sites were chosen for this study based on a history of sorghum and soybean production from 1984 to 1990. One site near Newton in south-central Mississippi, U.S.A., had a Prentiss fine loam soil (70% sand, 18% silt and 12% clay) with a 6.5 pH and 1.0% organic matter. The other two sites in east-central Mississippi were at Brooksville and Starkville. The Brooksville site had an Okolona silty clay soil (7% sand, 45% silt and 48% clay) with a pH of 7.5 and 2.0% organic matter, and the Starkville site had a Marietta sandy loam soil (61% sand, 25% silt and 14% clay) with a pH of 7.5 and 1.0% organic matter. The experimental design and treatments were identical for all locations in the 1990, 1991 and 1992 growing seasons.

Each test consisted of a factorial experiment with the 2 crop species in 3 rotations and 4 nematicide or insecticide treatments on soybean and 3 on sorghum. Replications were arranged in a randomized complete block. Soybean at each site was treated with trifluralin [2,6-*N,N*- dipropyl-4-(trifluoromethyl) benzenamine] for weed control prior to planting, and sorghum was treated post-emergence. Plots consisted of 4 rows 12 m long spaced on 91 cm centers. Blocks were separated by alleys 6 m wide to minimize the distribution of nematodes with tillage equipment. Sorghum cv. Seneca was planted at all locations. Soybean cv. Tracy M was chosen because of known susceptibility to the cyst nematode. Sorghum and soybean were planted at the rate of 23 and 26 seeds per m of row, respectively.

Continuous sorghum and soybean plots were planted in the same blocks each year and were alternated in rotation blocks from season to season. Aldicarb [2-methyl-2(methylthio) propionaldehyde 0- (methylcarbamoyl) oxime] and phorate (0,0-diethyl S-ethylthiomethyl phosphorodithioate) were applied in furrow at 1.18 and 0.84 kg a.i./ha, respectively. Ethoprop (0-ethyl S,S-dipropyl phosphorodithioate) and terbufos [S-[(1,l-dimethylethyl) thio] methyl] 0,0-diethyl phosphorodithioate] were applied to soybean in a 20-cm band over the row at 1.57 and 1.18 kg a.i./ha, respectively. Terbufos was also applied to sorghum. Following emergence, sorghum was side-dressed with 45 kg of nitrogen. Corn earworm [*Helicoverpa zea* (Boddie)] was controlled on sorghum with methomyl [S-methyl-N-[(methylcarbamoyl)oxy] thioacetimidate] insecticide.

Soil samples for nematode analysis consisted of 10 to 12 cores, each 15 to 20-cm-deep and 2.5-cm in diam, taken from the center 2 rows of each plot. Samples taken within each plot were collected at planting, midseason, and at harvest. Nematodes were extracted from a 500 $cm^3$ subsample with a semi-automatic elutriator (2). The shaker-incubation method was used to extract endoparasitic nematodes from 4 g of root tissue (1). Seed were harvested at maturity from the center two rows of each plot. Grain yield was adjusted to 13% moisture, and yield was converted to kg/ha. All data were subjected to analysis of variance for determination of significance and means separated by Fisher's least significant difference test.

## RESULTS

No significant differences in spiral nematode (*Helicotylenchus* spp.) reproduction were found among rotations. The interaction of year and rotation was significant for this nematode. Despite this interaction, in 1992 spiral nematode reproduction exceeded the three-year average for all 4 rotations (Table 1). Reproduction in 1992 was significantly higher than reproduction in 1991 in continuous soybean, in soybean rotated with sorghum in 1990, and in continuous sorghum in both 1990 and 1991. The highest numbers of this nematode were found in 1992 on continuously cropped sorghum.

A significant two-way interaction between location and year for lesion nematode (*Pratylenchus zeae* Graham) reproduction was found. On the fine sandy loam soil at Newton, reproduction was significantly higher in 1990 than either of the other two years (Table 2). Reproductive rates at Brooksville on the silty clay soil, and at Starkville on the sandy loam soil, were very low.

A significant three-way interaction was recorded between location, year and rotation for both stunt (*Tylenchorhynchus* spp. and *Quinisulcius acutus* Siddiqui) and cyst reproduction. Both stunt and cyst nematodes reproduced on soybean (Table 2). Stunt nematode numbers were highest at Brooksville on monocropped sorghum in 1992. This level of reproduction was significantly different than that attained in rotational sorghum or soybean. Stunt nematode reproduction was higher in 1992 than the three-year average for both crops in all rotations at this location. The situation was similar at the Newton location in 1990 when stunt reproduction was higher than the three-year average for all rotations for both crops.

Cyst nematode numbers were greatest on soybean in 1992 at the Brooksville and Starkville locations regardless of rotation (Table 2). The highest reproduction at Newton occurred in 1990. In these years at the 3 locations, reproduction was equal to or greater than the three-year average. Insecticide or nematicide treatment had no significant effect on nematode populations on either host at any location during the 3 years of study.

Seed yield of grain sorghum grown in rotation with soybean was enhanced compared to monocropped sorghum (Table 3). The significant interaction of location and year was reflected in maximum yield at a different location each year Starkville, Brooksville and Newton in 1990, 1991 and 1992, respectively. These responses were the same for continuously

Table 1. Effect of rotation on populations of *Helicotylenchus* spp. in soybean and sorghum in Mississippi during 1990, 1991 and 1992.

| Year | Continuous Soybean | Soybean in rotation | Continuous sorghum | Sorghum in rotation | Mean | LSD[y] |
|---|---|---|---|---|---|---|
| 1990 | 51[z] | 9 | 6 | 22 | 22 | 29 |
| 1991 | 37 | 71 | 22 | 49 | 45 | 39 |
| 1992 | 102 | 109 | 258 | 51 | 130 | 159 |
| Mean | 63 | 63 | 95 | 41 | | |
| LSD[y] | 52 | 78 | 162 | 46 | | |

[y]Significant LSD values at $P \leq 0.05$.
[z]Reproductive factor = final population/initial population.

Table 2. Effect of rotation on the lesion nematode (*Pratylenchus zeae*), stunt nematodes (*Tylenchorhynchus* spp., *Quinisulcius acutus*), and cyst nematode (*Heterodera glycines*) in soybean and sorghum at three locations in Mississippi during 1990, 1991, and 1992.

| | | | Stunt | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Year | Lesion | Monocropped soybean | Soybean in rotation | Monocropped sorghum | Sorghum in rotation | Mean | LSD[z] |
| Brooksville | 1990 | 10[z] | 8 | 3 | 0 | 0 | 3 | 6 |
| | 1991 | 0 | 49 | 20 | 21 | 28 | 30 | NS |
| | 1992 | 0 | 205 | 436 | 1195 | 777 | 653 | 348 |
| | Mean | 3 | 87 | 153 | 405 | 268 | | |
| | LSD | NS | 174 | 251 | 427 | 423 | | |
| Starkville | 1990 | 0 | 0 | 5 | 0 | 6 | 1 | 6 |
| | 1991 | 4 | 3 | 39 | 3 | 0 | 11 | NS |
| | 1992 | 7 | 0 | 0 | 0 | 0 | 0 | — |
| | Mean | 4 | 1 | 15 | 1 | 2 | | |
| | LSD | NS | NS | NS | NS | 1 | | |
| Newton | 1990 | 40 | 117 | 256 | 92 | 231 | 174 | NS |
| | 1991 | 1 | 0 | 5 | 53 | 14 | 18 | 36 |
| | 1992 | 15 | 42 | 6 | 33 | 28 | 27 | NS |
| | Mean | 19 | 53 | 89 | 59 | 91 | | |
| | LSD | 22 | 105 | NS | NS | 164 | | |

| | | Cyst | | | | | |
|---|---|---|---|---|---|---|---|
| | Year | Monocropped Soybean | Soybean in rotation | Monocropped Sorghum | Sorghum in rotation | Mean | LSD[y] |
| Brooksville | 1990 | 0 | 0 | 0 | 0 | 0 | — |
| | 1991 | 38 | 8 | 2 | 1 | 12 | 22 |
| | 1992 | 710 | 279 | 7 | 5 | 250 | 124 |
| | Mean | 249 | 96 | 3 | 2 | | |
| | LSD | 274 | NS | NS | NS | | |
| Starkville | 1990 | 3 | 15 | 0 | 0 | 5 | 10 |
| | 1991 | 8 | 2 | 1 | 4 | 4 | 6 |

[z]Significant (P≤0.05) LSD values.

Table 2. (Continued) Effect of rotation on the lesion nematode (*Pratylenchus zeae*), stunt nematodes (*Tylenchorhynchus* spp., *Quinisulcius acutus*), and cyst nematode (*Heterodera glycines*) in soybean and sorghum at three locations in Mississippi during 1990, 1991, and 1992.

| | | Cyst | | | | | |
|---|---|---|---|---|---|---|---|
| | Year | Monocropped Soybean | Soybean in rotation | Monocropped Sorghum | Sorghum in rotation | Mean | LSD[z] |
| | 1992 | 62 | 231 | 1 | 4 | 75 | 159 |
| | Mean | 24 | 83 | 1 | 3 | | |
| | LSD | 55 | NS | NS | NS | | |
| Newton | 1990 | 16 | 221 | 46 | 3 | 72 | 165 |
| | 1991 | 13 | 14 | 7 | 0 | 9 | 10 |
| | 1992 | 20 | 70 | 12 | 1 | 26 | 67 |
| | Mean | 16 | 102 | 22 | 1 | | |
| | LSD | NS | 177 | NS | NS | | |

[z]Significant ($P \leq 0.05$) LSD values.

cropped and rotated sorghum. In 1992 at the Brooksville location, sorghum seed yield in plots treated with aldicarb was statistically higher than in untreated control plots (Table 4). In 1992 at the Newton location, phorate caused a significant reduction in yield. Phorate also resulted in significant yield reduction in 1991 at Starkville.

Growing soybean in a one-year rotation with sorghum enhanced yield compared to monocropped soybean. Although there was a significant location by year interaction, yield was highest at the Starkville location in all 3 years on the Marietta sandy loam soil (Table 5). In 1990 a significant yield response to all chemical treatments was found on continuous soybean at the Starkville location (Table 6). Soybean grown in rotation with sorghum did not respond to treatment. The only other positive treatment response occurred in 1991 at Brooksville when terbufos application resulted in a significant yield increase. Phorate application at Newton in 1992 reduced yield significantly.

## DISCUSSION

Spiral, lesion, stunt and cyst nematode populations increased on soybean and sorghum in at least one year of a three-year study at 3 different locations. Soil moisture during the preceding growing season may have influenced nematode population development. At the Brooksville location, populations of stunt and cyst nematodes were highest in 1992, a year when total precipitation was 56 cm from May to September following a total of 71 cm during the same period in 1991. At Starkville, the cyst population was highest in 1992 when total precipitation was 51 cm during the growing season following 61 cm in 1991. Both stunt and cyst populations were highest at Newton in 1990 following

Table 3. Yield of sorghum grown continuously or in rotation with soybean at three locations in Mississippi from 1990 to 1992.

| | Location | Yield[y] 1990 | 1991 | 1992 | Mean | LSD[z] |
|---|---|---|---|---|---|---|
| Continuous sorghum | Brooksville | 3000[z] | 4161 | 3327 | 3666 | 364 |
| | Newton | 1682 | 1557 | 4701 | 2712 | 280 |
| | Starkville | 6013 | 3270 | 3446 | 4375 | 437 |
| | Mean | 3565 | 2996 | 3823 | | |
| | LSD | 437 | 336 | 546 | | |
| Sorghum in rotation | Brooksville | 3189 | 4293 | 3910 | 3797 | 502 |
| | Newton | 2103 | 1883 | 4839 | 2944 | 703 |
| | Starkville | 5793 | 3779 | 4237 | 4601 | 471 |
| | Mean | 3697 | 3320 | 4331 | | |
| | LSD | 728 | 289 | 659 | | |

[y]Expressed in kg/ha and averaged across treatments. [z]Significant LSD values at $P \leq 0.05$.

71 cm of precipitation during the 1989 growing season. This finding is supported by Koenning *et al.* (14) who reported that the effect of planting date on final soybean cyst nematode populations depended on local environmental factors. In Georgia, both infective juveniles and eggs were recovered in greatest numbers from

Table 4. Yield of sorghum treated with nematicide/insecticide at three locations in Mississippi from 1990 to 1992.

| Treatment[x] | Brooksville 1992 | Newton 1990 | Newton 1992 | Starkville 1991 |
|---|---|---|---|---|
| Terbufos | 3779[y] | 2034 | 5172 | 4325 |
| Aldicarb | 3885 | 1770 | 5266 | 3810 |
| Phorate | 3722 | 1921 | 3258 | 2950 |
| Control | 3302 | 1908 | 5266 | 4136 |
| Mean | 3622 | 1889 | 4770 | 3722 |
| LSD[z] | 508 | NS | 439 | 446 |

[x]Terbufos, aldicarb and phorate applied at 1.18, 1.18 and 0.84 kg a.i./ha respectively.
[y]Expressed in kg/ha and averaged across rotations.
[z]Significant LSD values at $P \leq 0.05$.

Table 5. Yield of soybean grown continuously or in rotation with sorghum at three locations in Mississippi from 1990 to 1992.

| | Location | Yield 1990 | Yield 1991 | Yield 1992 | Mean | LSD[y] |
|---|---|---|---|---|---|---|
| Continuous soybean | Brooksville | 881[z] | 1876 | 1628 | 1459 | 209 |
| | Newton | 740 | 888 | 1944 | 1190 | 323 |
| | Starkville | 2387 | 2838 | 2502 | 2576 | 397 |
| | Mean | 1338 | 1870 | 2024 | | |
| | LSD | 444 | 262 | 330 | | |
| Soybean in Rotation | Brooksville | 834 | 1897 | 1984 | 1574 | 343 |
| | Newton | 942 | 1022 | 2065 | 1345 | 316 |
| | Starkville | 2482 | 2979 | 2737 | 2730 | 558 |
| | Mean | 1419 | 1964 | 2260 | | |
| | LSD | 504 | 188 | 336 | | |

[y]Significant LSD values at $P \leq 0.05$.
[z]Expressed in kg/ha and averaged across treatments.

Table 6. Yield of monocropped soybean treated with nematicide/insecticide at three locations in Mississippi from 1990 to 1992.

| | Brooksville | Newton | Starkville | |
|---|---|---|---|---|
| Treatment[y] | 1991 | 1992 | 1990 | 1992 |
| Terbufos | 1984[z] | 2031 | 2535 | 2656 |
| Ethoprop | 1923 | 2078 | 2320 | 2650 |
| Aldicarb | 1930 | 1997 | 2455 | 2636 |
| Phorate | 1769 | 1856 | 2549 | 2562 |
| Control | 1816 | 2065 | 2065 | 2589 |
| Mean | 1883 | 2004 | 2387 | 2616 |
| LSD | 141 | 195 | 202 | NS |

[y]Terbufos, ethoprop, aldicarb and phorate applied at 1.18, 1.57, 1.18 and 0.84 kg ai/ha, respectively.
[z]Expressed in kg/ha and averaged across rotations except at Starkville in 1990 when rotation × treatment was significant.

soybean receiving optimal moisture compared to treatments where moisture was limiting (3).

The few positive yield responses in sorghum or soybean treated with insecticides or nematicides indicates that the materials tested in this study have limited use when rotation is practiced for maximum production on soil types such as those described. Significant negative responses to treatments with materials not labeled for a particular crop were not unexpected. However, such responses to materials that are labeled and recommended remain unexplained. Previous reports have documented that soils high in organic matter provide suitable environments for biological control agents of plant pests (17). Although the lack of response to treatments in the study suggest that soilborne insects and/or nematodes did not significantly impact yield, soilborne organisms susceptible to biological control agents could have been present. The activity of such organisms could also account, in part, for the observed responses to crop rotation. In north Mississippi, continuous culture of soybean in no-till systems increases cyst nematode populations but not to a level that causes yield reduction (12).

Enhanced yield of maize grown in rotation with soybean, compared to continuous maize culture, has been reported previously (5,7,15). This response also was found for sorghum at all locations. Advantage also accrued to soybean in rotation with sorghum where enhanced yield occurred in 2 of the 3 seasons. Although all differences were not statistically significant, their occurrence over 3 seasons on different soil types at 3 locations may be important to producers. Francl and Dropkin (6) reported that two- and three-year, but not one-year, rotation with a nonhost resulted in significant soybean yield increase in soil infested with *H. glycines*. In this study, a one-year rotation resulted in some yield improvement for both sorghum and soybean.

Pesticides that have been used for effective disease management are under scrutiny because of potential effects to both human and animal health. Many pesticides have been banned because of persistence in the environment, potential carcinogenic effects, and damage to the atmospheric ozone layer. For these and for economic reasons, producers continue to seek effective pest control measures. On soils in the Coastal Plain and Prairie land resource areas of Mississippi, rotation of sorghum and soybean in alternate years provides yield advantages that cannot be achieved with insecticide or nematicide application to these crops in rotation or continuous culture.

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