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Velvetbean in Rotation with Soybean for Management of *Heterodera glycines* and *Meloidogyne arenaria*

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Abstract: The effect of previous crops—soybean (*Glycine max*) or velvetbean (*Mucuna deeringiana*)—and aldicarb on yield and nematode numbers for selected soybean cultivars was studied in a field infested with a mixture of *Meloidogyne arenaria* and *Heterodera glycines.* Soybean following velvetbean yielded 959 kg/ha more than soybean following soybean. Nematicide treatment resulted in increased yield, and there was no interaction between nematicide treatment and previous crop. Cultivars interacted significantly with nematicide treatment but not with previous crop for yield. Velvetbean reduced numbers of *H. glycines* but not *M. arenaria.* Cultivars interacted with previous crop, and the previous crop × nematicide × cultivar interaction was significant for both *M. arenaria* and *H. glycines.* We concluded that velvetbean is effective in reducing yield losses caused by mixed populations of *M. arenaria* and *H. glycines,* regardless of genetic resistance of soybean cultivar.

Key words: Alabama, aldicarb, biodiversity, crop rotation, *Glycine max, Heterodera glycines,* host-plant resistance, *Meloidogyne arenaria, Mucuna deeringiana,* nematode, root-knot nematode, soybean cyst nematode, soybean, velvetbean.

Meloidogyne spp. and *Heterodera glycines* are frequently major pests of soybean (*Glycine max*) in the southeastern United States (8,16). Often these nematode pathogens occur in the same fields, and yields can be reduced to such an extent that economic production in a monoculture system is not possible (21). Crop rotation and genetic resistance are currently the only major management tools available that are effective and economical in fields where mixed populations of *Meloidogyne* spp. and *H. glycines* occur (13,14).

Rotation with grass crops such as grain sorghum (*Sorghum bicolor*) (13), bahiagrass (*Paspalum notatum*) (14), and maize (*Zea mays*) (22) has been highly effective in increasing yield of soybean following the rotation crop, especially for nematode-susceptible cultivars. Although susceptible cultivars often show a large relative yield increase in response to rotation, highest-yielding treatments usually involve cultivars with genetic resistance following the rotation crop (13,14,22). Other (dicotyledonous) rotation crops have been tried with limited success, including American jointvetch (*Aeschynomene americana*) (15), hairy indigo (*Indigofera hirsuta*) (15), upland cotton (*Gossypium hirsutum*), and sesame (*Sesamum indicum*) (Rodríguez-Kábana and Weaver, unpubl.). Rotation with non-host crops for nematode control depends not only on yield response but on economic, ecological, and other constraints faced by growers in individual situations (17).

Velvetbean (*Mucuna deeringiana*) is an African legume that has been used in the southern United States as a forage and cover crop. The value of velvetbean as a crop for managing *Meloidogyne* spp. has been recognized for a long time (19). Root exudates of velvetbean are known to suppress *Meloidogyne* spp. (18), and the rhizosphere bacteria of velvetbean are markedly different from those of soybean and other crops (9). Velvetbean is not a host for *M. arenaria, M. incognita, M. javanica,* and *H. glycines* (11). It has also been effective as a rotation crop for management of *M. arenaria* in peanut (*Arachis hypogaea*), increasing yield by 47% compared with peanut monoculture (10).

The effectiveness of velvetbean as a rotation crop for management of parasitic nematodes in soybean is unknown. The objective of this experiment was to determine the value of velvetbean as a rotation crop with soybean in a field infested with a mixture of *M. arenaria* and *H. glycines.*

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Materials and Methods

The experiment was conducted in 1991 and 1992 near Elberta, Alabama, on a Norfolk sandy loam soil (fine loamy, siliceous, thermic, Typic Paleudults, pH 6.2, <1.0% organic matter) naturally infested with a mixture of *M. arenaria* and *H. glycines* of unknown races. Fertilizer was applied (54 and 67 kg/ha K as KCl broadcast in 1991 and 1992, respectively) to raise fertility to recommended levels (4). In 1991, metolachlor (2.2 kg a.i./ha) and paraquat (0.3 kg a.i./ha) were applied with a nonionic surfactant at a concentration of 0.125% v/v for pre-emergence weed control. Later, fomesafen (0.4 kg a.i./ha) and bentazon (1.1 kg a.i./ha) were applied broadcast with crop oil concentrate (vegetable) at a concentration of 1.0% v/v to control late-emerging weeds. The same herbicides were used in 1992, except that glyphosate (1.5 kg a.e./ha) was used instead of paraquat in the pre-emergence herbicide treatment. In 1991, insects were controlled with an initial broadcast application of permethrin (0.2 kg a.i./ha) plus methyl parathion (0.5 kg a.i./ha), with three later broadcast applications of acephate (0.8 kg a.i./ha). Insect pressure was light in 1992, and only the broadcast application of permethrin plus methyl parathion (same rate as 1991) was made. Effects of foliar and stem diseases were minimal. No significant stem diseases were observed, and the only foliar diseases were those that normally occur during the late part of the growing season in a humid, subtropical environment, such as anthracnose (caused by *Colletotrichum truncatum*). Frogeye leafspot (caused by *Cercospora sojina*), a disease that occurs frequently in this area, was not present. The area was tilled with a moldboard plow followed by a disk harrow before planting in 1991 and 1992.

The field had been planted in a soybean cultivar evaluation test for 3 years (1988–90) prior to the experiment. Individual plots were sampled in 1990 exactly as described in a previous experiment (14) and showed nematode populations ranging from 41 to 1,197 juveniles/100 cm^3 soil for *M. arenaria* and 0 to 340 juveniles/100 cm^3 for *H. glycines*. Low *H. glycines* numbers were associated only with cultivars that had resistance to *H. glycines* races 3 and 14. Plot areas that would later correspond to replications in 1992 had mean populations that ranged from 238 to 567 juveniles/100 cm^3 soil for *M. arenaria* and 12 to 169 juveniles/100 cm^3 soil for *H. glycines*. Mean nematode populations for the entire test area in 1990 were 374 juveniles/100 cm^3 soil for *M. arenaria* and 80 juveniles/100 cm^3 soil for *H. glycines*.

In 1991 the field was divided into two blocks each 112.5 m × 60 m, with half of each block planted to velvetbean and half planted to soybean cultivar Kirby. In 1992 seven soybean cultivars selected to have a range in host response to *M. arenaria* and *H. glycines* (Table 1) were planted (5 June) within these split blocks in a 2 × 7 factorial treatment structure with and without aldicarb. Treatments were placed in eight randomized complete blocks within each split block. A 15G formulation of aldicarb was applied at 17.8 g a.i./100 m of row (2.2 kg a.i./ha) in a 25-cm band over the row with an electric-driven Gandy applicator (Gandy Co., Owatonna, MN) and incorporated 2–3 cm deep just before planting. Plots were two rows, 7.5 m long with 0.81 m between rows. A composite soil sample was collected from each split block on 26 October 1991 to determine the immediate effect of velvetbean on nematode popula-

Table 1. Host response of soybean cultivars to *Meloidogyne arenaria* and *Heterodera glycines* races 3 and 14.

Cultivar	Maturity group	*M. arenaria*	*H. glycines* Race 3	*H. glycines* Race 14	Reference
Braxton	VII	R†	S	S	(7)
Brim	VI	S	S	S	(3)
Bryan	VI	R	R	S	(2)
Kirby	VIII	R	R	S	(5)
Leflore	VI	S	R	R	(6)
Stonewall	VII	S	R	S	(20)
Thomas	VII	S	R	S	(1)

† R = resistant; S = susceptible.

tions. Soil samples were collected from each plot for nematode analysis on 27 October 1992. Samples consisted of a composite of 15–20 soil cores (2.5-cm-d) taken from the root zone 20–25 cm deep. Nematodes were extracted from a 100-cm^3 subsample by a modified Baermann method (12). Seed yield was obtained by harvesting the entire area of each plot with a small plot combine. All data were subjected to analysis of variance, with the previous crop × block interaction used to test the effect of previous crop, and the replications within blocks × all other effects mean squares (pooled) was used to test the other main effects and interactions. Means were separated using Fisher's least significant difference (P = 0.05).

Results and Discussion

Numbers of *M. arenaria* and *H. glycines* juveniles were much lower in 1991 in velvetbean than soybean. Average number of *M. arenaria* was 12 juveniles/100 cm^3 soil in velvetbean and over 1,200 juveniles/100 cm^3 soil in Kirby soybean. *H. glycines* was undetectable in velvetbean and averaged 12 juveniles/100 cm^3 soil in soybean. Thus velvetbean appeared effective in lowering soil numbers of both nematode species.

Soybean yield was 105% higher following velvetbean than following soybean averaged across cultivars and nematicide treatment (1,876 kg/ha vs. 917 kg/ha) (Table 2). The cultivar × previous crop interaction was not significant (Table 3), indicating that yield response to rotation was not related to cultivar or genetic resistance; however, cultivars differed in yield. The highest yielding cultivar was Leflore, the only cultivar with resistance to *H. glycines* race 14. Other high-yielding cultivars (Thomas, Bryan, and Kirby) are all resistant to *H. glycines* race 3. *Meloidogyne arenaria* resistance seemed to have little effect on yield because Braxton and Kirby, resistant to *M. arenaria,* did not yield more than susceptible cultivars.

Aldicarb treatment increased yield by 150 kg/ha averaged over previous crop and cultivars. Yield response to nematicide was independent of previous crop but was dependent on cultivar (Table 3). Most cultivars yielded higher following aldicarb

Table 2. Effect of previous crop, aldicarb,† and soybean cultivar on yield and juvenile numbers of *Meloidogyne arenaria* and *Heterodera glycines.*

		Continuous soybean			Velvetbean–soybean		
			Juveniles/100 cm^3 soil			Juveniles/100 cm^3 soil	
Cultivar	Aldicarb application	Yield (kg/ha)	*M. arenaria*	*H. glycines*	Yield (kg/ha)	*M. arenaria*	*H. glycines*
Braxton	−	625	63	82	1736	243	44
Braxton	+	887	36	69	1835	144	32
Brim	−	633	116	12	1519	284	9
Brim	+	712	114	6	1767	258	20
Bryan	−	1048	67	23	2029	179	24
Bryan	+	974	42	23	1935	149	18
Kirby	−	1021	68	28	1788	146	22
Kirby	+	1021	87	29	1956	340	35
Leflore	−	1075	133	6	2083	276	10
Leflore	+	1384	109	2	2305	200	5
Stonewall	−	692	121	54	1561	223	29
Stonewall	+	894	38	91	1788	285	14
Thomas	−	840	50	60	1868	160	24
Thomas	+	1021	100	48	2110	170	28
$\bar{x}$	−	848	88	38	1794	216	23
$\bar{x}$	+	985	75	38	1957	221	21

Data are averages of 16 replications. LSD (0.05) values for comparing any two means are 186, 56, and 17 for yield, *M. arenaria* populations, and *H. glycines* populations, respectively.
† Aldicarb applied at 17.8 g a.i./100 m row in a 25-cm band.

TABLE 3. Analysis of variance for soybean yield and juvenile numbers of *Meloidogyne arenaria* and *Heterodera glycines* following a previous crop of velvetbean or soybean and treated with aldicarb at 2.2 kg a.i./ha.

Source	df†	Mean squares ($\times 10^{-3}$)		
		M. arenaria	*H. glycines*	Soybean yield
Previous crop (P)	1	2072.4	28.8*	102,667.6*
Error a	1	605.5	0.2	680.5
Nematicide (N)	1	1.3	0.1	2,427.7**
P × N	1	10.4	0.2	19.1
Cultivar (C)	6	68.1**	22.8**	2,309.8**
P × C	6	16.3*	8.0**	83.6
N × C	6	51.3**	1.1	233.9**
P × N × C	6	39.0**	2.3**	58.3
Error b	390	6.5	0.6	72.1

† Blocks have 1 degree of freedom, and replicates within block and previous crop have 28 degrees of freedom.
* $P = 0.05$, ** $P = 0.01$.

treatment, except Bryan and Kirby, which have the same spectrum of resistance. The reason for this was not clear, but appeared to have little to do with genetic resistance.

Velvetbean reduced *H. glycines* numbers in the subsequent soybean crop compared with continuous soybean (Table 3). Average numbers of *H. glycines* were 22 juveniles/100 cm^3 soil following velvetbean vs. 36 juveniles/100 cm^3 soil following soybean. This is similar to a previous study (22), in which corn reduced *H. glycines* numbers in the following soybean crop compared with continuous soybean; however, it is in contrast to another study (13), in which soybean following sorghum had higher *H. glycines* numbers than continuous soybean. Cultivars differed for numbers of *H. glycines,* as Leflore (resistant to race 14) had lower numbers than all other cultivars except Brim. Brim had high numbers of *M. arenaria,* however, and low *H. glycines* numbers in Brim may have been due to increased competition from *M. arenaria* for feeding sites. Previous crop effects on *H. glycines* numbers were cultivar-dependent (Table 3). Velvetbean generally suppressed *H. glycines* more in cultivars that supported large *H. glycines* populations (Braxton, Stonewall, and Thomas). The suppressive effect of velvetbean was less for cultivars with low *H. glycines* numbers (Brim, Bryan and Leflore) (Table 2). Aldicarb had no effect on numbers of *H. glycines.*

Neither previous crop nor aldicarb had any effect on numbers of *M. arenaria* juveniles (Table 3). Cultivars were significantly different, but cultivar response to aldicarb differed. Averaged over previous crop, *M. arenaria* numbers were lower in aldicarb-treated plots for Braxton and Leflore, higher for Kirby, and no different for other cultivars. The previous crop × cultivar interaction was also significant for numbers of *M. arenaria,* but the interaction mean square was small in magnitude and was probably related to reduced plant vigor of lower-yielding cultivars in the continuous soybean plots.

Results of this study were similar to other studies in this same field area involving rotation crops for nematode management, with the notable exception that this was a legume–legume rotation rather than grass–legume. Magnitude of yield response to rotation was similar to that obtained with bahiagrass (110%) (14) and grain sorghum (85%) (13), but the overall yield level of this experiment was higher. Another major difference between this and previous studies was the lack of a previous crop × cultivar interaction for yield. In all of our other studies where soybean responded to rotation (13,14,22), nematode-susceptible cultivars had a much higher yield response than nematode-resistant cultivars. In the current study, there was no such previous crop × cultivar interaction for yield, but the highest-yielding cultivar was Leflore, the only cultivar with genetic resistance to *H. glycines* race 14. The potential of velvetbean as an agronomic crop is unknown.

Literature Cited

1. Boerma, H. R., R. S. Hussey, D. V. Phillips, and E. D. Wood. 1989. Registration of 'Thomas' soybean. Crop Science 29:489–490.

2. Boerma, H. R., R. S. Hussey, D. V. Phillips, E. D. Wood, and S. L. Finnerty. 1991. Registration of 'Bryan' soybean. Crop Science 31:487.

3. Burton, J. W., T. E. Carter, Jr., and E. B. Huie. 1993. Registration of 'Brim' soybean. Crop Science 33:(in press).

4. Cope, J. T., Jr., C. E. Evans, and H. C. Williams. 1981. Soil test fertilizer recommendations for Alabama soils. Circular 252, Agricultural Experiment Station, Auburn University, AL.

5. Hartwig, E. E., and C. J. Edwards, Jr. 1987. The uniform soybean tests, Southern Region, 1986. USDA Mimeographed Report. Washington, DC: U.S. Government Printing Office.

6. Hartwig, E. E., L. D. Young, and C. J. Edwards, Jr. 1985. Registration of 'Leflore' soybean. Crop Science 25:1128–1129.

7. Hinson, K., R. A. Kinloch, H. A. Peacock, W. H. Chapman, and W. T. Scudder. 1981. Braxton soybean. Florida Agricultural Experiment Station Circular S-276.

8. Kinloch, R. A. 1980. The control of nematodes injurious to soybean. Nematrópica 10:141–153.

9. Kloepper, J. W., R. Rodríguez-Kábana, J. A. McInroy, and D. J. Collins. 1991. Analysis of populations and physiological characterization of microorganisms in rhizospheres of plants with antagonistic properties to phytopathogenic nematodes. Plant and Soil 136:95–102.

10. Rodríguez-Kábana, R., J. W. Kloepper, D. G. Robertson, and L. W. Wells. 1992. Velvetbean for the management of root-knot and southern blight in peanut. Nematrópica 22:75–79.

11. Rodríguez-Kábana, R., J. Pinochet, D. G. Robertson, and L. Wells. 1992. Crop rotation studies with velvetbean (*Mucuna deeringiana*) for the management of *Meloidogyne* spp. Supplement to the Journal of Nematology 24:662–668.

12. Rodríguez-Kábana, R., and M. H. Pope. 1981. A simple method for extraction of nematodes from soil. Nematrópica 11:175–176.

13. Rodríguez-Kábana, R., D. B. Weaver, D. G. Robertson, P. S. King, and E. L. Carden. 1990. Sorghum in rotation with soybean for the management of cyst and root-knot nematodes. Nematrópica 20: 111–119.

14. Rodríguez-Kábana, R., D. B. Weaver, R. García, D. G. Robertson, and E. L. Carden. 1989. Bahiagrass for the management of root-knot and cyst nematodes in soybean. Nematrópica 19:185–193.

15. Rodríguez-Kábana, R., D. B. Weaver, D. G. Robertson, R. W. Young, and E. L. Carden. 1990. Rotations of soybean with two tropical legumes for the management of nematode problems. Nematrópica 20:101–110.

16. Schmitt, D. P. 1985. Plant-parasitic nematodes associated with soybeans. Pp. 541–546 *in* R. M. Shibles, ed. World soybean research conference III proceedings. Boulder, CO: Westview Press.

17. Trivedi, P. C., and K. R. Barker. 1986. Management of nematodes by cultural practices. Nematrópica 16:213–236.

18. Vincente, N. E., and N. Acosta. 1987. Effects of *Mucuna deeringiana* on *Meloidogyne incognita*. Nematrópica 17:99–102.

19. Watson, J. R. 1922. Bunch velvetbeans to control root-knot. Agricultural Experiment Station Bulletin 163. Gainesville: University of Florida.

20. Weaver, D. B., R. Rodríguez-Kábana, and H. R. Boerma. 1989. Registration of 'Stonewall' soybean. Crop Science 29:1329.

21. Weaver, D. B., R. Rodríguez-Kábana, and E. L. Carden. 1988. Multiple-species nematode resistance in soybean: Effect of genotype and fumigation on yield and nematode numbers. Crop Science 28:293–298.

22. Weaver, D. B., R. Rodríguez-Kábana, D. G. Robertson, R. L. Akridge, and E. L. Carden. 1988. Effect of crop rotation on soybean in a field infested with *Meloidogyne arenaria* and *Heterodera glycines*. Supplement to the Journal of Nematology (Annals of Applied Nematology) 20:106–109.