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Galling and Yields of Soybean Cultivars Grown in *Meloidogyne arenaria*-Infested Soil[1]

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Abstract: Field trials with 39 soybean cultivars and five breeding lines from public and private sources were conducted from 1982 through 1985 at sites infested with *Meloidogyne arenaria.* Nematode population densities and root-knot galling were measured for each soybean entry. All were efficient hosts for the nematode, and average juvenile numbers in the soil increased 5–50× from planting to harvest.

Differences ($P < 0.05$) in galling were found among entries in each year. Centennial, Cobb, Coker 368, Hutton, and Jeff cultivars, recognized for their resistance to *M. incognita,* were severely galled and yielded poorly. Bedford, Forrest, A7372, Bragg, Braxton, Gordon, and Kirby, also recognized for their resistance to *M. incognita,* were among the least galled cultivars. Yields of all entries, however, were too low to justify their planting in sites heavily infested with *M. arenaria.*

Key words: Glycine max, Meloidogyne arenaria, root-knot nematode, soybean, susceptibility.

During the last decade growers and extension personnel have reported more frequent damage by the peanut root-knot nematode, *Meloidogyne arenaria* (Neal) Chitwood on soybean, *Glycine max* (L.) Merr., in Florida, Alabama (9), and South Carolina (4). The most widespread and damaging nematodes in soybean production in the southeastern states have been the southern root-knot nematode, *M. incognita* (Kofoid & White) Chitwood, and the soybean cyst nematode, *Heterodera glycines* Ichinohe (6). Increased incidence of *M. arenaria* damage to soybean may be due to widespread planting of *M. incognita*- and *H. glycines*-resistant soybean cultivars. Several of these are highly susceptible to *M. arenaria.*

Successful development of *M. incognita*-resistant cultivars by screening for low galling in the presence of high soil infestations of this nematode (8) has encouraged breeders in the public and private sectors to employ a similar approach in developing cultivars with suitable agronomic traits for production in areas infested with *M. arenaria.* Soybean cultivars and breeding lines have been evaluated annually for agronomic traits and susceptibility to pathogens at various sites throughout the soybean production area of Florida (10). At sites infested with *M. arenaria,* entries included cultivars and breeding lines from public and private sources selected for their promising responses to this nematode, together with known susceptible cultivars. The purposes of this study were to compare the galling and yields of 39 cultivars and five breeding lines grown in *M. arenaria*-infested soil and to evaluate their potential for *M. arenaria* management.

MATERIALS AND METHODS

Experiments were conducted from 1982 through 1985 in a field naturally infested with *M. arenaria* near Allentown, Santa Rosa County, Florida. The soil was a loamy sand (80% sand, 12% silt, 8% clay, < 2% organic matter) fertilized each year with 10 N, 30 P_2O_5, and 60 K_2O at 200 kg/ha. Experiments were arranged in a randomized complete block design with four replicates per cultivar or breeding line. Each plot consisted of three rows 8.2 m long and 0.9 m apart. Alleys 1 m wide separated the blocks. Nematode population density in the soil was determined immediately before planting and at harvest. Seven soil cores 2.5 cm d and 20 cm deep were taken from a 15-cm-wide band along the center row of each plot. The cores were mixed and the nematodes extracted from a 100-cm^3 sample by centrifugal flotation (5). The nematode suspension was dispersed on a

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TABLE 1. Nematode density, galling, and yields of soybean cultivars and breeding lines grown in *Meloidogyne arenaria*-infested soil in 1982. Data are averages of four observations.

Entry	J2 per 10 cm³ soil†		Galling‡	Yield (kg/ha)
	Pi	Pf		
Kirby	6 n.s.	128 n.s.	0.8 de	1,928 a
Braxton	5	105	0.8 de	1,838 ab
A7372	7	109	1.3 cde	1,687 abc
Bedford	4	104	0.5 e	1,646 abc
Forrest	7	58	1.0 de	1,341 a–d
Foster	9	105	2.1 a–d	1,324 a–d
A6520	9	111	0.5 e	1,290 a–d
Bragg	7	78	1.8 b–e	1,194 b–e
RA 701	10	118	2.8 ab	1,156 b–f
Centennial	7	110	2.4 abc	1,114 b–g
Sumter	5	95	2.8 ab	983 c–h
RA 800	7	77	2.5 abc	897 d–i
RA 604	6	41	2.4 abc	827 d–i
Hutton	13	127	2.4 abc	522 e–i
Coker 368	7	61	2.7 abc	514 e–i
S69-96	8	125	3.3 a	482 e–i
Terra-Vig 606	10	105	3.5 a	473 e–i
Cobb	4	219	2.9 ab	439 f–i
S72-60	2	85	3.4 a	371 ghi
Terra-Vig 708	4	65	3.1 ab	365 ghi
Coker 237	10	110	2.9 ab	346 hi
HB-507-DI-7	6	80	3.4 a	253 hi
RA X83	8	101	3.3 a	231 hi
Davis	7	102	3.3 a	220 i

Averages followed by the same letter within a column are not significantly ($P < 0.05$) different according to Duncan's multiple-range test.

† Pi—sampled at planting, 1 June; Pf—sampled at harvest, 9 November.

‡ Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

gridded dish, and the nematodes per 10 cm³ soil were counted.

Approximately 30 seeds per meter were planted on 1 June 1982, 27 May 1983, 27 June 1984, and 4 June 1985. The cultivars and breeding lines are listed by source and maturity group. Public: Bedford and Forrest (Group V); Centennial, Davis, and Jeff (Group VI); Bragg, Braxton, Gordon, and Wright (Group VII); Cobb, F77-7446, Foster, Hutton, and Kirby (Group VIII). Asgrow Seed Co., Marion, AR: A6520 (Group VI); A7372 (Group VII). CR Seeds, Hartsville, SC: Coker 485 (Group V); Coker 686 (Group VI); Coker 237, Coker 627, and Coker 6727 (Group VII); Coker 368, Coker 488, and Coker 6738 (Group VIII). Delta and Pine Land Co., Wilson, NC: DP 566 (Group VI). HY Performer Seed Co., Memphis, TN: Sumter (Group VI); HB-507-DI-7 (Group VII). Jacob Hartz Seed Co., Stuttgart, AR: Hartz 5370 (Group V); Hartz 6130 (Group VI); Hartz 7126 (Group VII). Northrup King Co., Dallas, TX: S69-96 (Group VI); S72-60 (Group VII). Rohm and Haas Seeds, Inc., Philadelphia, PA: RA 604 and RA 680 (Group VI); RA 701 and RA X223 (Group VII); RA 800, RA 801, RA C17, RA C28, and RA X83 (Group VIII). Terral-Norris Seed Co., Inc., Lake Providence, LA: Terra-Vig 606 (Group VI); Terra-Vig 708 (Group VII); Terra-Vig 808 (Group VIII). Nine cultivars (Bedford, Centennial, Braxton, Cobb, Kirby, A7372, Coker 368, S69-96, and Terra-Vig 708) were planted each year for continuity among the tests. Plots were cultivated and hand weeded when necessary. Root-knot galling in each plot was scored when plants had reached the V12–V13 stage of development (3). Two groups of four plants from each border row were rated according to

TABLE 2. Nematode density, galling, and yields of soybean cultivars and breeding lines grown in *Meloidogyne arenaria*-infested soil in 1983. Data are averages of four observations.

Entry	J2 per 10 cm^3 soil†		Galling‡	Yield (kg/ha)
	Pi	Pf		
Kirby	34 n.s.	114 abc	1.8 ef	848 a
A7372	14	113 abc	2.1 c–f	567 b
Foster	21	94 abc	2.8 a–e	501 bc
RA 604	9	64 abc	1.9 def	412 bcd
Bedford	18	132 abc	1.9 def	374 cd
Braxton	8	143 a	1.5 f	354 cd
Bragg	8	113 abc	2.1 c–f	338 cde
Forrest	16	41 c	2.3 c–f	255 def
RA 701	6	109 abc	3.0 abc	161 efg
Terra-Vig 808	8	136 ab	2.9 a–d	155 efg
RA 800	18	60 abc	2.9 a–d	150 efg
RA C28	4	125 abc	2.3 c–f	79 fg
S72-60	18	51 abc	3.6 ab	73 fg
Cobb	7	63 abc	2.8 a–e	65 fg
Centennial	11	85 abc	3.8 a	57 fg
Coker 368	25	40 c	3.8 a	57 fg
RA C17	17	43 bc	2.6 b–e	49 g
Hutton	9	76 abc	3.1 abc	28 g
Davis	19	40 c	3.6 ab	23 g
Coker 237	19	39 c	3.8 a	17 g
S69-96	20	70 abc	3.8 a	17 g
Terra-Vig 708	10	54 abc	3.6 ab	14 g

Averages followed by the same letter within a column are not significantly ($P < 0.05$) different according to Duncan's multiple-range test.
† Pi—sampled at planting, 27 May; Pf—sampled at harvest, 20 October.
‡ Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

the following scale: 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% of the root surface galled. The middle row of each plot was harvested at crop maturity, and yields were adjusted to 13% moisture content.

RESULTS

In addition to *M. arenaria,* we found *Helicotylenchus dihystera* (Cobb) Sher, *Pratylenchus scribneri* Steiner, *Paratrichodorus porosus* Allen, and *Hoplolaimus galeatus* (Cobb) Sher at the experimental sites but in numbers considered too low to influence soybean production. Initial population densities (Pi) of second-stage juveniles (J2) of *M. arenaria* were not different among plots to be planted to soybean cultivars and lines in any year. The Pi averages in the successive tests were 7, 15, 2, and 1 per 10 cm^3 soil. Average J2 population densities following harvest (Pf) in the successive tests were 101, 83, 108, and 57 per 10 cm^3 soil. Differences ($P < 0.05$) in final population densities (Pf) among entries occurred in 1983 and 1985 (Tables 2, 4) but Pi, Pf, or Pf/Pi were not correlated with galling or yield across entries in any of the tests.

Differences ($P < 0.05$) in galling were found among entries in each test (Tables 1–4). Galling was greater in 1983 and 1984 than in 1982 and 1985, but certain cultivars were consistently less galled. Of the nine cultivars grown each year, Braxton, Kirby, Bedford, and A7372 were significantly ($P < 0.05$) less galled (Table 5). Although evaluated only twice, Forrest, Bragg, and Gordon had galling equivalent to Braxton and Kirby. Alternatively, Centennial, Cobb, Coker 368, S69-96, and Terra-Vig 708 were consistently among the most severely galled entries each year. Yield data for the nine cultivars varied greatly from year to year. Average yields in 1982 and 1983 (1,113 and 261 kg/ha) were different ($P < 0.01$) from those in 1984 and

TABLE 3. Nematode density, galling, and yields of soybean cultivars and breeding lines grown in *Meloidogyne arenaria*-infested soil in 1984. Data are averages of four observations.

Entry	J2 per 10 cm³ soil†		Galling‡	Yield (kg/ha)
	Pi	Pf		
A7372	1 n.s.	99 n.s.	3.0 cd	1,465 a
Kirby	1	154	2.9 d	1,268 ab
Gordon	0	99	2.9 d	1,144 abc
Hartz 5370	2	84	2.9 d	1,073 abc
Braxton	1	102	3.1 bcd	1,049 abc
Wright	1	136	3.3 abc	1,034 abc
Coker 686	4	101	3.6 a–d	993 abc
F77-7446	3	126	3.7 a–d	938 a–d
Terra-Vig 808	3	102	3.7 a–d	788 b–e
Hartz 7126	5	162	4.0 a	784 b–e
Coker 627	2	182	3.8 abc	776 b–e
Centennial	1	102	3.9 a	731 b–f
Bedford	1	108	3.0 cd	707 c–g
Jeff	2	89	3.9 a	602 c–h
RA 801	2	122	3.8 a–d	426 d–h
Coker 368	0	131	3.8 abc	421 d–h
RA 680	3	90	3.8 abc	406 d–h
Terra-Vig 708	3	122	4.0 a	353 e–h
RA X223	3	105	3.8 a–d	216 fgh
S69-96	1	92	3.9 a	194 fgh
Coker 488	2	94	4.0 a	182 gh
DP 566	4	82	4.0 a	170 gh
Hutton	1	27	3.9 a	95 h
Cobb	6	84	4.0 a	77 h

Averages followed by the same letter within a column are not significantly ($P < 0.05$) different according to Duncan's multiple-range test.
† Pi—sampled at planting, 27 June; Pf—sampled at harvest, 26 November.
‡ Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

1985 (696 and 797 kg/ha). There was a negative correlation between yield and galling within early season cultivars (Maturity Groups V and VI), mid season cultivars (Maturity Group VII), and late season cultivars (Maturity Group VIII) (Table 6).

Differences ($P < 0.05$) in yields among cultivars and lines occurred in all tests (Tables 1–4). Kirby, A7372, and Braxton had higher average yields than the more severely galled cultivars Centennial, Coker 368, Cobb, and S69-96 (Table 5). Bedford, which was among the least galled cultivars, had intermediate yields.

Discussion

The absence of relationships between soil population densities of *M. arenaria* juveniles and soybean galling and yield within a given crop season casts doubt on the usefulness of measuring soil densities to distinguish soybean cultivar differences. A similar conclusion was reached with respect to soil population densities of *M. incognita* and soybean cultivars (8). Soil population densities increased on all cultivars and lines in these tests, indicating that all entires were efficient hosts for this nematode.

Although all cultivars and breeding lines were galled, consistent differences among entries showed that selection for reduced galling has been successful. Although significant negative regressions of yield with galling were present within maturity groups in most years, the correlations were considerably weaker than previously found for *M. incognita* on similar soybean cultivars (8). This could be due to the narrower range of galling among cultivars to *M. arenaria* than was found for *M. incognita*. Also

TABLE 4. Nematode density, galling, and yields of soybean cultivars and breeding lines grown in *Meloidogyne arenaria*-infested soil in 1985. Data are averages of four observations.

Entry	J2 per 10 cm³ soil† Pi	J2 per 10 cm³ soil† Pf	Galling‡	Yield (kg/ha)
Kirby	0 n.s.	41 c–f	0.5 gh	1,342 a
Coker 6738	0	37 ef	1.0 fgh	1,259 ab
Coker 6727	1	38 ef	1.3 e–h	1,251 ab
Hartz 6130	1	40 def	1.1 fgh	1,134 abc
Wright	0	56 b–f	1.4 d–h	1,107 a–d
Foster	0	61 b–f	2.5 a–d	1,107 a–d
Gordon	2	37 ef	0.4 h	1,077 a–e
Braxton	0	43 b–f	1.1 fgh	1,026 a–f
Hartz 5370	1	38 ef	0.9 fgh	987 a–f
Bedford	0	61 b–f	1.6 d–g	946 a–f
RA 680	0	68 b–f	2.3 a–e	936 a–f
Coker 485	1	37 ef	1.7 b–f	898 a–f
Coker 686	1	34 f	1.7 b–f	851 b–f
A7372	0	45 b–f	1.7 b–f	815 b–f
Centennial	1	61 b–f	2.9 ab	786 c–g
Coker 368	2	86 abc	2.8 abc	777 c–g
Hartz 7126	1	88 ab	1.9 a–f	725 c–g
Coker 488	0	47 b–f	2.6 a–d	702 c–g
Jeff	1	60 b–f	2.4 a–e	682 c–g
Cobb	1	85 a–d	2.4 a–e	642 d–h
Coker 627	0	80 a–e	2.3 a–e	628 e–h
Terra-Vig 708	0	111 a	2.5 a–e	605 fgh
RA 801	1	56 b–f	2.3 a–e	361 gh
S69-96	0	64 b–f	2.9 a	239 h

Averages followed by the same letter within a column are not significantly ($P < 0.05$) different according to Duncan's multiple-range test.

† Pi—sampled at planting, 4 June; Pf—sampled at harvest, 4 November.

‡ Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

galling of a given cultivar displays much greater variation with *M. arenaria* than with *M. incognita*. For example, Kirby galling ranged from 0.5 to 2.9 and Braxton ranged from 0.8 to 3.1. Both of these cultivars, which were among the least galled in these tests, are resistant to *M. incognita*. Under comparable conditions, galling of both cul-

TABLE 5. Average nematode density, galling, and yields of selected soybean cultivars grown in *Meloidogyne arenaria*-infested soil, 1982–85.

Entry	J2 per 10 cm³ soil† Pi	J2 per 10 cm³ soil† Pf	Galling‡	Yield (kg/ha)
Kirby	10 n.s.	109 n.s.	1.5 b	1,346 a
A7372	5	97	2.0 b	1,133 ab
Braxton	3	98	1.6 b	1,067 ab
Bedford	6	101	1.8 b	918 bc
Centennial	5	89	3.3 a	673 cd
Coker 368	9	79	3.3 a	442 de
Terra-Vig 708	4	88	3.3 a	334 e
Cobb	4	113	3.0 a	306 e
S69-96	7	88	3.5 a	233 e

Averages followed by the same letter within a column are not significantly ($P < 0.05$) different according to Duncan's multiple-range test.

† Pi—sampled at planting; Pf—sampled at harvest.

‡ Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

TABLE 6. Relationships between yield (Y) and galling (X) of early, mid, and late season maturing soybean cultivars grown in *Meloidogyne arenaria*-infested soil, 1982–85.

Year	Maturity†	Regression equation‡	Coefficient of correlation (*r*)
1982	Early	Y = 1,825 − 363X	−0.71**
	Mid	Y = 2,235 − 539X	−0.76**
	Late	Y = 2,042 − 509X	−0.83**
1983	Early	Y = 613 − 148X	−0.93**
	Mid	Y = 752 − 182X	−0.71**
	Late	Y = 1,054 − 266X	−0.74**
1984	Early	Y = 1,735 − 329X	−0.60*
	Mid	Y = 2,699 − 519X	−0.70**
	Late	Y = 3,890 − 921X	−0.87**
1985	Early	No relationship	
	Mid	No relationship	
	Late	Y = 1,278 − 188X	−0.75**

* $P < 0.05$, ** $P < 0.01$.

† Early (Groups V and VI): Bedford, Centennial, and S69-96. Mid (Group VII): Braxton, A7372, and Terra-Vig 708. Late (Group VIII): Kirby, Cobb, and Coker 368.

‡ Yield (Y)—kg/ha; galling (X)—rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 5–25%, 2 = 26–50%, 3 = 51–75%, and 4 = > 75% root surface galled.

tivars was consistently less than 1.0 when exposed to *M. incognita* in 3 years of testing (8). Similar comparisons can be made for other cultivars. No explanation is offered for this phenomenon other than the host response of the more resistant cultivars to *M. arenaria* is apparently more variable than it is to *M. incognita.*

Yields for all entries in these tests were less than required for a profitable return. This was especially the case in 1983 (Test 2) when the experimental site was excessively wet in the early season. With the exception of Kirby and Braxton in 1982, all cultivar yields in these tests were considerably less than the Florida soybean yield average of 1,698 kg/ha (1) over the experimental period. Some cultivars such as Cobb, Coker 368, and Centennial, which have gained wide grower acceptance for their resistance to *M. incognita,* were consistently poor yielders. According to recently proposed host-response terminology (2), all cultivars evaluated in these tests must be considered susceptible to *M. arenaria* since they were efficient hosts and suffered damage from the nematode. Galling indicated, however, that several cultivars were consistently less susceptible than others. These were Bedford and Forrest in Maturity Group V; A7372, Bragg, Braxton, and Gordon in Maturity Group VII; and Kirby in Maturity Group VIII. Other entries, such as A6520 and Hartz 6130 (Maturity Group VI), Coker 6727 (Maturity Group VII), and Coker 6738 (Maturity Group VIII), had significantly lower galling but were evaluated only once. All of the aforementioned entries have resistance to *M. incognita* (8) and might be grown in sites known to be infested by both species of root-knot nematodes. Growing these cultivars in fields heavily infested with *M. arenaria* will be precarious, as indicated by the yields reported from these tests. Currently there are no nematicides that can produce an economic soybean yield response in heavily infested sites (7). Planting nonhosts would be a more expedient management practice when infestations of *M. arenaria* are severe. At sites adjacent to those used for these tests, growers have resorted to planting the nonhost cotton (*Gossypium hirsutum* L.) or summer fallowing. Although progress has been achieved in selecting soybean cultivars with reduced galling to *M. arenaria,* further efforts are necesssary to produce cultivars suitable for planting in severe infestations of this nematode.

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