Comparative Root-Knot Galling and Yield Responses of Soybean Cultivars to *Meloidogyne incognita*

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ABSTRACT

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Field trials containing resistant and susceptible soybean cultivars were conducted from 1981 through 1983 on a loamy sand infested with *Meloidogyne incognita*. Nematode populations were monitored and root-knot galling was evaluated. Yields were negatively correlated to the amount of root-knot galling in the three trials, but soil nematode populations at harvest were correlated in only one trial. Yields from resistant cultivars were five times greater than those from highly susceptible cultivars.

Additional key words: *Glycine max*, southern root-knot nematode resistance

Southern root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood) is ubiquitous in the southeastern United States (7) and is a limiting factor in the production of soybean (*Glycine max* (L.) Merr.), a major crop of the region. Management of this nematode had been primarily by soil fumigation with DBCP or EDB (4,6). Use of these chemicals has been prohibited because of environmental concerns (1,8). Lack of economic alternatives for these fumigants has placed more emphasis on the use of resistant soybean cultivars for root-knot nematode management. Development of resistant cultivars is based on screening plant introductions and breeding lines for development of root galls when grown in the presence of the nematode (5). This was accomplished initially by breeders in the public sector, but the importance of root-knot nematodes in soybean culture has encouraged seed companies to develop resistant cultivars.

The purposes of these studies were to compare the yield of 34 soybean cultivars from both public and private sources when grown in sites naturally infested with *M. incognita* and to determine any relationships between root-knot galling, nematode population density, and soybean yield.

MATERIALS AND METHODS

Experiments were conducted in 1981–1983 in fields naturally infested with *M. incognita* at the University of Florida, Agricultural Research and Education Center, Jay. Soil at the sites was a loamy sand ultisol-typic paleudult (70% sand, 15% silt, 15% clay) fertilized each year with $0N:30P_2O_5:15K_2O$ at 300 kg/ha. Trifluralin was preplant incorporated at 0.6 kg/ha for weed control. Experiments were arranged in a randomized complete block design with four replicates per cultivar. Each plot consisted of three 8.2-m rows 0.9 m apart. Alleys 1 m wide separated the plots. Nematode population density in the soil was determined immediately before planting and at harvest. Seven soil cores 2.5 cm in diameter 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 (3). An aliquot of the nematode suspension of each sample was dispersed in a gridded dish, and the nematodes were counted. About 30 seeds per meter were planted on 4 June 1981, 25 May 1982, and 26 May 1983. The cultivars are listed by source and maturity group. Public: Bedford and Forrest (group V); Centennial and Davis (group VI); Bragg and Braxton (group VII); and Cobb, Foster, Hutton, Kirby, F77-1790, and F77-1840 (group VIII). Asgrow Seed Co., Marion, AR: A5939 (group V); A6520 (group VI); and A7372 (group VII). Coker's Pedigree Seed Co., Hartville, SC: Coker 237 (group VII) and Coker 338, Coker 368, and Coker 488 (group VIII). Helena Chemical Co., Memphis, TN: Brysoy 9 and Sumter (group VI); HB507-D1-7 and Wilstar 790 (group VII). Northrup King Co., Bolivar, TN: S69-96 (group VI) and S72-60 (group VII). Ring Around Products, Plainview, TX: RA604 (group VI); RA701 and RA702 (group VII); and RA800, RA801, and RAX83 (group VIII). Terral-Norris Seed Co., Lake Providence, LA: Terra-Vig 606 (group VI); Terra-Vig 708 (group VII); and Terra-Vig 808 (group VIII).

Plots were cultivated and hand weeded as necessary. Insects were controlled with insecticides. Root galling in each plot was scored in August of each year by rating

Table 1. Root-knot galling, nematode abundance, and soybean yield in 1981

Cultivar	Root-knot galling[y]	*Meloidogyne incognita* juveniles per 10 cm^3 of soil at harvest	Yield (kg/ha)
Braxton	0.05 c[z]	28 d	3,000 a
F77-1790	0.02 c	46 cd	2,933 ab
Foster	0.05 c	21 d	2,919 ab
RA800	0.00 c	112 bcd	2,818 ab
Hutton	0.02 c	57 cd	2,778 ab
Centennial	0.02 c	52 cd	2,731 abc
Bragg	0.02 c	66 cd	2,711 abc
RA701	0.02 c	45 cd	2,704 abc
Kirby	0.02 c	41 cd	2,684 abc
F77-1840	0.00 c	22 d	2,502 abcd
Cobb	0.30 bc	67 cd	2,408 bcd
Bedford	0.65 bc	45 cd	2,394 bcd
Coker 338	0.92 bc	256 a	2,193 cd
Coker 488	1.30 b	187 ab	2,065 d
Forrest	0.65 bc	70 cd	2,025 d
Brysoy 9	1.27 b	149 bc	1,964 d
Wilstar 790	3.62 a	133 bcd	760 e

[y] Root-knot galling index: 0 = no galling, 0.2 = <5%, 1 = 6–25%, 2 = 26–50%, 3 = 51–75%, and 4 = >75% of root surface galled.

[z] Means within columns followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's multiple range test.

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two groups of four plants from each border row according to the following scale: 0 = no galling; 0.2 = trace, less than 5%; 1 = slight, 6–25%; 2 = moderate, 26–50%; 3 = severe, 51–75%; and 4 = very severe, more than 75% of the root surface galled. The middle row of each plot was harvested, and yields are reported in kilograms per hectare adjusted to 13% moisture content.

RESULTS AND DISCUSSION

In addition to *M. incognita*, *Helicotylenchus dihystera* (Cobb), *Pratylenchus scribneri* Steiner and *Paratrichodorus christiei* Allen occurred in the plots. Populations of these nematodes were low and were not considered to affect soybean growth. Initial numbers of *M. incognita* present in the soil in 1981 averaged one per 10 cm^3, and no significant differences occurred among plots ($P < 0.05$). At harvest, the average number of juveniles in all plots was 82 per 10 cm^3 of soil. The range was 22 with F77-1840 to 256 with Coker 338 (Table 1). Root-knot gall ratings ranged from 0.00 with RA800 and F77-1840 to 3.62 with Wilstar 790, the most susceptible entry in the trial. Wilstar 790 was the lowest yielding cultivar at 760 kg/ha, whereas Braxton was the highest yielding cultivar at 3,000 kg/ha.

Initial soil infestations of *M. incognita* juveniles averaged two per 10 cm^3 of soil in 1982. No significant differences were found among the plots. The average number of juveniles in all plots at harvest was 119 per 20 cm^3 of soil. The counts ranged from 46 per 10 cm^3 of soil with HB507-D1-7 to 255 with Terra-Vig 606 (Table 2). Root-knot gall ratings ranged from 0.07 with Kirby, the highest yielding entry, to 4.00 with Davis, one of the lowest yielding entries.

Initial soil infestations of *M. incognita* juveniles averaged 22 per 10 cm^3 of soil in 1983. There were no significant differences among plots. The average number at harvest was 170 per 10 cm^3 of soil and the number ranged from 63 with A5939 to 467 with Terra-Vig 708 (Table 3). These two cultivars were among the lowest yielding in the trial. Root-knot galling ranged from 0.15 with Kirby to 4.00 with A5939, and yields ranged from 117 kg/ha with A5939 to 2,621 kg/ha with Kirby.

Significant negative correlations ($P < 0.01$) between root-knot gall ratings and soybean yield occurred in all three trials (Table 4). Numbers of *M. incognita* juveniles in the soil at harvest were negatively correlated ($P < 0.05$) with soybean yield only in 1982.

Absence of a clear relationship between yield and soil infestation is possibly caused by inadequate food resources available for nematode reproduction when roots of susceptible cultivars become severely parasitized and deteriorated. This phenomenon would result in higher residual soil infestation levels following resistant cultivars than following more susceptible cultivars. Juveniles in the soil may not be a good criterion on which to gauge resistance and susceptibility.

Soybean yields were inversely related to the amount of root galling caused by the presence of *M. incognita*. The average yield of highly susceptible cultivars (average gall ratings >3) was 539 kg/ha across all three trials. Susceptible cultivars (gall ratings 2 to <3) averaged 1,226 kg/ha. Moderately resistant cultivars (gall ratings 1 to <2) averaged 2,192 kg/ha, whereas resistant cultivars (gall ratings <1) yielded 2,483 kg/ha. Yields in the two latter categories were considerably higher than the Florida state average yield (1,682 kg/ha) over the same years (2).

Breeding soybeans for low root-galling

Table 2. Root-knot galling, nematode abundance, and soybean yield in 1982

Cultivar	Root-knot galling[y]	*Meloidogyne incognita* juveniles per 10 cm^3 of soil at harvest	Yield (kg/ha)
Kirby	0.07 f[z]	63 cd	3,032 a
Foster	0.20 f	54 cd	2,950 a
Centennial	0.17 f	61 cd	2,828 a
Braxton	0.32 ef	74 bcd	2,794 a
RA800	0.90 ef	186 abcd	2,781 a
A7372	0.40 ef	68 cd	2,760 a
Coker 368	0.35 ef	94 abcd	2,747 a
Cobb	0.60 ef	113 abcd	2,659 ab
HB507-D1-7	0.27 ef	46 d	2,645 ab
RA701	1.17 e	97 abcd	2,611 ab
Hutton	0.50 ef	107 abcd	2,577 ab
RA604	0.25 ef	36 d	2,523 ab
Bragg	0.40 ef	116 abcd	2,523 ab
Sumter	0.82 ef	108 abcd	2,475 ab
Bedford	0.30 ef	69 cd	2,408 ab
Forrest	0.72 ef	96 abcd	2,069 bc
Terra-Vig 606	2.87 cd	218 abc	1,743 c
Terra-Vig 708	2.12 d	255 a	1,709 c
S72-60	3.50 abc	145 abcd	1,573 cd
A6520	2.50 d	96 abcd	1,133 d
Coker 237	2.30 d	57 cd	1,119 d
RAX83	3.00 bcd	186 abcd	1,065 d
Davis	4.00 a	170 abcd	1,017 d
S69-96	3.75 ab	235 ab	983 d

[y] Root-knot galling index: 0 = no galling, 0.2 = <5%, 1 = 6–25%, 2 = 26–50%, 3 = 51–75%, 4 = >75% of root surface galled.
[z] Means within columns followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's multiple range test.

Table 3. Root-knot galling, nematode abundance, and soybean yield in 1983

Cultivar	Root-knot galling[y]	*Meloidogyne incognita* juveniles per 10 cm^3 of soil at harvest	Yield (kg/ha)
Kirby	0.15 g[z]	154 bcdef	2,621 a
Foster	0.52 fg	121 cdef	2,576 a
Centennial	0.22 g	143 cdef	2,542 a
Coker 368	0.15 g	257 bc	2,499 a
RA801	0.67 fg	155 bcdef	2,449 a
Braxton	0.52 fg	108 def	2,220 ab
Bragg	0.85 efg	208 bcde	2,167 abc
Cobb	1.00 efg	140 cdef	2,167 abc
A7372	1.75 de	254 bc	1,944 bc
Sumter	1.30 def	107 ef	1,943 bc
RA702	0.27 g	96 ef	1,920 bc
Hutton	0.57 fg	247 bcd	1,897 bc
RA604	0.87 efg	137 cdef	1,863 bc
Bedford	1.32 def	136 cdef	1,802 bc
Forrest	0.95 efg	88 ef	1,673 c
S72-60	2.00 cd	288 b	1,145 d
Terra-Vig 708	3.12 ab	467 a	978 d
Coker 237	2.62 bc	195 bcdef	406 e
Davis	3.75 a	139 cdef	248 e
S69-96	3.37 ab	99 ef	200 e
Terra-Vig 808	3.87 a	136 cdef	143 e
A5939	4.00 a	63 f	117 e

[y] Root-knot galling index: 0 = no galling, 0.2 = <5%, 1 = 6–25%, 2 = 26–50%, 3 = 51–75%, 4 = >75% of root surface galled.
[z] Means within columns followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's multiple range test.

Table 4. Regression equations and correlation coefficients between soybean yield (Y)[a] and root-knot galling indices (X)[b] and between yield and population densities of *Meloidogyne incognita* juveniles (Z)[c] in field plot experiments conducted in 3 yr

Year	Equation	Correlation coefficient[d]
1981	$Y = 2,696.9 - 463.3X$	−0.82**
1982	$Y = 2,798.1 - 456.8X$	−0.82**
	$Y = 2,359.7 - 1.32Z$	−0.24*
1983	$Y = 2,484.8 - 564.9X$	−0.86**

[a] Kilograms per hectare.
[b] Root galling index: 0 = no galling, 0.2 = <5%, 1 = 6–25%, 2 = 26–50%, 3 = 51–75%, and 4 = >75% of root surface galled.
[c] Numbers per 10 cm^3 of soil at harvest.
[d] * = $P<0.05$, ** = $P<0.01$.

responses has been very successful in developing cultivars with resistance to *M. incognita*. All three trials reported here were conducted at sites subject to considerable root-knot nematode stress. Several cultivars, however, had only trace amounts of root-knot galling. The equations relating yield to root-knot galling (Table 4) determine an increase of about 100 kg/ha if these trace amounts of galling are alleviated. This indicates limited opportunity for improving on the resistance now obtained. Resistant cultivars are available in maturity groups V–VIII. Cultivars in maturity group V have borderline adaptability to the photoperiodic conditions in Florida. Consequently, Bedford and Forrest consistently yielded less than other resistant cultivars in these trials. Differences in yield caused by intrinsic agronomic traits among resistant cultivars are greater than the comparative losses they sustain when exposed to the southern root-knot nematode.

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