Response of Soybean Cultivars to Nematicidal Treatments of Soil Infested with Meloidogyne incognita[1]

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Abstract: A comparison of untreated and nematicide-treated soil for soybean production revealed that *Meloidogyne incognita* hastened crop maturity and reduced plant ht, seed wt, and yield. Reductions of yield varied from 32-90% depending on cultivar susceptibility. DBCP was more consistent in increasing crop performance than organo-phosphate or oxime carbamate nematicides. Greatest yield increases were produced by nematicidal treatment of soils planted to soybean cultivars with the lowest susceptibility. *Key Words: Glycine max*, control, resistance, root-knot, population dynamics, nematode.

Acreage planted to soybean, *Glycine max* (L.) Merr., in the southern United States has more than doubled in the last decade. The importance of this crop in the agricultural economy requires a greater knowledge of the role of plant parasitic nematodes in its production. Most research concerning nematode damage to soybean has involved the soybean cyst nematode, *Heterodera glycines* Ichinohe, 1952 (5). However, in many areas, particularly the Southern Coastal Plain, including North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi, the southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949, is an equally important, or probably a more serious pest of soybean under current practices. In a recent survey of soybean fields in Florida, I found 40% of the fields sampled infested with *M. incognita.*

Root-knot nematode disease is a problem because of the widespread occurrence of indigenous root-knot nematode populations, the continuous use of highly susceptible soybean cultivars, and the absence of rotational practices that could curb nematode population increases. The disease has become a limiting factor in soybean production in some localities (7) and evaluation of *M. incognita* susceptibility is an integral part of the breeding and development of soybean cultivars adapted to southern latitudes (6).

Published studies on root-knot disease of soybean have been largely confined to reports of disease incidence and recognition of degrees of susceptibility in several soybean cultivars (1, 2, 4, 8, 9).

The purposes of the experiments reported here were to determine yield losses of soybean cultivars infected with *M. incognita* and to evaluate the efficacy of nematicides to control *M. incognita* and to influence bean yields.

MATERIALS AND METHODS

In 1970 and 1971, plots were established in Escambia County, Florida, in a field of well-drained deep-phase Ruston loamy fine sand uniformly infested with *M. incognita.* The plots were 6 m long and four rows wide on 0.9 m centers in a randomized complete block design, replicated four times. Nematicides used were aldicarb, carbofuran, oxamyl, ethoprop, fensulfothion, phenamiphus, DBCP, and 1,3D.

DBCP and 1,3D were applied as liquid formulations with a chisel applicator with one chisel per row 15 cm deep; 1,3D was applied 20 days before planting and DBCP at planting. Other nematicides, with the exception of foliar applications of oxamyl, were applied as granular formulations in a 38-cm band over the row and incorporated by rotary-tiller into the top 10-cm of soil immediately prior to planting. Rates are given in Table 1.

The susceptible cultivar 'Hood' and the resistant cultivar 'Bragg' were tested in 1970 (Test I) and the susceptible cultivar 'Hampton 266A' and Bragg in 1971 (Test II). Replicated untreated plots for each cultivar were included.

In 1972 plots were established at the University of Florida, Agricultural Research Center, Jay, Florida in a field of Red Bay fine sandy loam infested with *M. incognita.* Plots were 9 m long and two rows wide on 0.9 m centers.

DBCP, fensulfothion, ethoprop, and carbofuran were compared for their effectiveness in root-knot nematode control and soybean yield increase on the susceptible cultivar 'Pickett 71', and on the resistant

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TABLE 1. Seed yield of 'Hood', 'Bragg', and 'Hampton 266A' soybeans grown in *Meloidogyne incognita*-infested soil treated with selected nematicides. Mean of four replicates.

Treatment	Rate (kg/ha)	Seed yield (kg/ha)[2] Test I Hood	Test I Bragg	Test II Hampton 266 A	Test II Bragg
Aldicarb	2.2 G[1]	1359 bc	2172 c		
	3.4 G			1608 cde	2462 ab
	4.5 G	1466 abc	2172 c		
Carbofuran	1.7 G			1513 def	1988 cd
	2.2 G	1123 c	2354 abc		
	3.4 G			1675 c d e	2051 cd
	4.5 G	1352 bc	2610 ab		
Oxamyl	2.2 L			1615 cde	1891 d
	1.1 G + 2.2 L			1513 def	2199 bcd
	2.2 G + 2.2 L			1675 cde	2341 bc
	1.1 G + 2.2 L +2.2 L	1446 abc	2206 bc		
	5.5 G	1675 abc	2482 abc		
Ethoprop	1.7 G			1567 de	2119 bcd
	2.2 G	1513 abc	2421 abc		
	3.4 G			1877 abcd	2018 cd
	4.5 G	1312 bc	2516 abc		
Fensulfothion	1.7 G			1473 def	1897 d
	2.2 G	1157 c	2596 ab		
	3.4 G			1567 de	2051 cd
	4.5 G	1312 bc	2596 ab		
Phenamiphus	1.7 G			1264 ef	1897 d
	2.2 G	1513 abc	2408 abc		
	3.4 G			1614 cde	2119 bcd
	4.5 G	1540 abc	2753 a		
1,3D	114.3 L	1675 abc	2536 abc		
DBCP	8.7 L	1386 bc	2455 abc		
	11.7 L	2032 a	2388 abc	2221 a	2699 a
DBCP + Oxamyl[3]	11.7 L + 2.2 L			2159 ab	2699 a
Check	—	209 d	1642 d	1050 f	1810 d
Average yield increase of all treatments over check		1248	802	617	364

[1] G = granular; L = liquid.
[2] The small letters in each column indicate Duncan's multiple range groupings. Entries with the same letter do not differ significantly ($P = 0.05$).
[3] DBCP preplant and oxamyl as a foliar spray 6 wk after planting.

cultivars 'Forrest', Bragg, 'Hutton', and 'Cobb' (formerly F66-1166). Treatments were replicated three times on each cultivar. Rates are given in Table 2.

All plots were sampled for nematodes prior to treatment and at 5-wk intervals after planting. Soil cores were taken at each 3 m of row (through the root zone postplant), composited to total approximately 1,500 ml, and mixed thoroughly. A 100-ml portion of the sample was wet-sieved and nematodes extracted by centrifugal flotation (3).

Maturation date and plant ht were recorded for each plot. Recorded seed yield and average seed wt (gm/100 seed) data were adjusted to a constant 14% moisture content.

RESULTS AND DISCUSSION

In Tests I and II (Table 1), the nematicides produced the greatest response on Hood and Hampton 266A, the susceptible cultivars. The average yield increase on Hood in Test I was 1248 kg/ha as opposed to 802 kg/ha for the resistant Bragg. In Test II, the average yield increase of Hampton 266A was 617 kg/ha as opposed to 364 kg/ha for Bragg. However, the highest total yields in both tests were produced by nematicidal treatment of the resistant cultivar, Bragg. Untreated plots of Bragg outyielded a majority of treated Hood and Hampton 266A in both tests.

Most nematicides were evaluated at two rate levels in each test (Table 1). Significant yield

TABLE 2. Numbers of *Meloidogyne incognita* juveniles per 100 ml soil from soybean cultivar plots treated with selected nematicides. Mean of three replicates. Test III.

Cultivar	Treatment	Rate (kg/ha)	Pretreat sample	Postplant samples 5 wk	10 wk	15 wk
'Forrest'	DBCP	11.7	41 a[1]	9 b	23 c	118 bc
	Fensulfothion	3.4	70 a	0 b	21 c	338 bc
	Ethoprop	3.4	41 a	0 b	23 c	250 bc
	Carbofuran	3.4	35 a	3 b	18 c	278 bc
	Check	—	15 a	20 b	15 c	323 bc
'Pickett 71'	DBCP	11.7	15 a	2 b	18 c	443 bc
	Fensulfothion	3.4	12 a	0 b	38 bc	708 b
	Ethoprop	3.4	18 a	2 b	79 b	1355 a
	Carbofuran	3.4	15 a	5 b	117 b	1403 a
	Check	—	15 a	100 a	232 a	1428 a
'Bragg'	DBCP	11.7	44 a	6 b	29 c	125 bc
	Fensulfothion	3.4	29 a	0 b	9 c	132 bc
	Ethoprop	3.4	65 a	15 b	38 bc	357 bc
	Carbofuran	3.4	17 a	3 b	59 bc	587 bc
	Check	—	38 a	12 b	61 bc	618 bc
'Hutton'	DBCP	11.7	27 a	6 b	9 c	57 c
	Fensulfothion	3.4	38 a	0 b	26 c	345 bc
	Ethoprop	3.4	12 a	0 b	15 c	128 bc
	Carbofuran	3.4	32 a	23 b	6 c	168 bc
	Check	—	3 a	12 b	35 bc	217 bc
'Cobb'	DBCP	11.7	6 a	6 b	12 c	162 bc
	Fensulfothion	3.4	32 a	0 b	32 bc	272 bc
	Ethoprop	3.4	35 a	0 b	29 c	258 bc
	Carbofuran	3.4	38 a	3 b	21 c	442 bc
	Check	—	35 a	21 b	68 bc	632 bc

[1] The small letters indicate Duncan's multiple range groupings which do not differ significantly ($P = 0.05$).

TABLE 3. Growth characteristics of soybean cultivars grown in soil infested with *Meloidogyne incognita* and treated with selected nematicides. Mean of three replicates. Test III.

Cultivar	Treatment	Rate (kg/ha)	Days to maturity	Height at maturity (cm)	Wt. of 100 seed (g)	Seed yield (kg/ha)
'Forrest'	DBCP	11.7	119 a[1]	53 a	10.9 a	2060 a
	Fensulfothion	3.4	115 c	47 a	9.8 a	1276 b
	Ethoprop	3.4	117 b	54 a	10.8 a	1615 b
	Carbofuran	3.4	117 b	50 a	10.0 a	1439 b
	Check	—	116 bc	46 a	10.0 a	1412 b
'Pickett 71'	DBCP	11.7	129 a	46 a	11.0 a	1392 a
	Fensulfothion	3.4	128 ab	36 b	9.5 b	713 b
	Ethoprop	3.4	127 bc	38 ab	9.6 b	558 b
	Carbofuran	3.4	128 ab	41 ab	9.4 b	599 b
	Check	—	125 c	35 b	8.5 b	552 b
'Bragg'	DBCP	11.7	134 a	68 a	12.6 a	1984 a
	Fensulfothion	3.4	132 b	66 a	10.6 ab	1197 b
	Ethoprop	3.4	132 b	66 a	10.8 ab	1345 b
	Carbofuran	3.4	132 b	69 a	10.9 ab	1412 b
	Check	—	129 c	64 a	10.1 b	1217 b
'Hutton'	DBCP	11.7	140 a	71 a	14.8 a	2038 a
	Fensulfothion	3.4	138 b	68 a	12.1 b	1406 bc
	Ethoprop	3.4	139 a	71 a	13.2 ab	1675 b
	Carbofuran	3.4	138 b	67 a	12.5 b	1560 bc
	Check	—	136 c	64 a	12.3 b	1352 c
'Cobb'	DBCP	11.7	141 a	81 a	10.2 a	2058 a
	Fensulfothion	3.4	141 a	80 a	9.9 a	1702 ab
	Ethoprop	3.4	141 a	82 a	9.9 a	1655 ab
	Carbofuran	3.4	140 a	76 a	10.5 a	1773 ab
	Check	—	140 a	76 a	9.8 a	1325 b

[1] Small letters in individual cultivar columns indicate Duncan's multiple range groupings which do not differ significantly ($P = 0.05$).

TABLE 4. Summary of yield increases due to 11.7 kg/ha DBCP treatment of resistant soybean cultivars in comparison with untreated resistant and susceptible cultivars grown in soil infested with *Meloidogyne incognita.*

Test no. and resistant cultivar	Soybean yield (kg/ha)			Yield increase and % of increase due to:			
	DBCP + resistance	Untreated resistant	Untreated susceptible	DBCP		Resistance	
I 'Bragg'	2388	1642	209[1]	746[4]	(34%)	1433[5]	(66%)
II 'Bragg'	2699	1810	1050[2]	889	(54%)	760	(46%)
III 'Forrest'	2060	1412	552[3]	648	(43%)	860	(57%)
III 'Bragg'	1984	1217	552[3]	767	(54%)	665	(46%)
III 'Hutton'	2038	1352	552[3]	686	(46%)	800	(54%)
III'Cobb'	2058	1325	552[3]	733	(49%)	773	(51%)
		Average percent increase			47%		53%

[1] 'Hood'.
[2] 'Hampton 266A'.
[3] 'Pickett 71'.
[4] Difference in yield between DBCP-treated and untreated resistant soybean plots.
[5] Difference in yield between untreated-resistant soybean and untreated-susceptible soybean plots.

increases between rates were noted only in the DBCP treatment of Hood, the most susceptible cultivar tested, where 11.7 kg/ha DBCP significantly outyielded 8.7 kg/ha.

All treatments significantly increased yields of Hood and Bragg in Test I. However, average yield increases were not so pronounced from treatments of Hampton 266A and Bragg in Test II the following year. Aldicarb was the only nonvolatile nematicide which increased the yield of Bragg as much the second year as it did the first. The volatile nematicide, DBCP, performed equally well in both years. The efficacy of the nonvolatile nematicides because of their slower action may be subject to early and mid-season climatic conditions, such as rainfall. In Test II, a secondary foliar treatment with oxamyl applied after an at-plant treatment with DBCP did not increase yield significantly above the treatment of DBCP applied alone.

Pretreatment distribution of infective juveniles of *M. incognita* was uniform throughout the test site prior to Test III (Table 2). Five wk after treatment and planting there was a marked reduction in nematode numbers in all treatments except the check plots of Pickett 71, the most susceptible cultivar in the test. This reduction could be due to nematicidal activity and/or invasion of roots by the juveniles. Root-knot nematode development is likely to be more rapid in more susceptible cultivars which could explain the larger numbers recovered from Pickett 71 as second-generation juveniles.

Ten wk after treatment, juveniles had increased to preseason levels in most treatments. Greatest increases were recovered from the check plots in Pickett 71 and the carbofuran treatment of the same cultivar. The Pickett 71 plots had the highest juvenile counts at the final nematode sampling 15 wk after planting. There were no significant differences between juvenile counts from any of the treatments of the four resistant cultivars at the final sampling.

Soybeans receiving nematicidal treatments tended to mature later than those not receiving treatment (Table 3). This was most pronounced in the DBCP treatments where maturity was significantly delayed in all cultivars except Cobb, where heavy late season rainfall removed much of the foliage of this late cultivar, obscuring an accurate assessment of maturity.

DBCP treatment significantly increased plant ht of the susceptible cultivar, Pickett 71 (Table 3). However, there were no significant differences in the plant ht in any of the treatments of the four resistant cultivars.

Seeds from DBCP-treated plots were significantly heavier than from untreated plots for all cultivars except Forrest and Cobb.

Greatest yields for all five cultivars were produced by DBCP treatments (Table 3). Cultivars grown on plots treated with DBCP significantly outyielded the respective check plot and all other treatments except for Cobb. Yields of the susceptible cultivar, Pickett 71, from DBCP-treated plots were equivalent to the yields of the check plots of the four resistant cultivars.

Pickett 71 yield was negatively correlated with juvenile *M. incognita* counts obtained at the final sampling ($r = -0.5516$, $P = 0.05$). Yields of Forrest, Bragg, Hutton, and Cobb were not correlated with juvenile counts. It is possible that nematode activity may have been less in the plots of the resistant cultivars producing the higher yields. The increase in juvenile numbers recorded from the resistant cultivar plots may indicate the selection and increase of races which parasitize these cultivars. This would explain the increase in yield of resistant cultivars following nematicidal treatment.

These studies have determined that the southern root-knot nematode, *Meloidogyne incognita,* hastens maturity and reduces plant ht, seed wt, and yield of soybean. These effects are more pronounced in cultivars with a greater susceptibility to the nematode. Root-knot nematode infestation reduced yields of susceptible cultivars by at least 53-90%, whereas yields of the more resistant cultivars were reduced by at least 32-40%.

Soybean yields can be increased by nematicidal treatment, by planting a resistant cultivar, and by both methods combined. The relative importance of both control practices can be determined from the data provided above. Comparison of yield data from treated and untreated resistant cultivars shows yield increases due to nematode control; comparison of yield data from untreated plots of resistant and susceptible cultivars shows yield increases due to cultivar selection. Applying these comparisions to the yield data from treatments with 11.7 kg/ha DBCP, the most consistent nematicide and rate reported here, one can determine that, even with the best nematicidal treatment, cultivar resistance accounts for half of the total soybean yield increase (Table 4).

Nematicidal treatment is a feasible means of improving soybean performance in soil infested with *M. incognita.* In the sandy soils of the Southern Coastal Plain, the fumigant, DBCP, was found to be more consistent and effective than either organo-phosphates or carbamates. Maximum yield response was achieved through the combination of nematicide application and selection of resistant soybean cultivars.

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