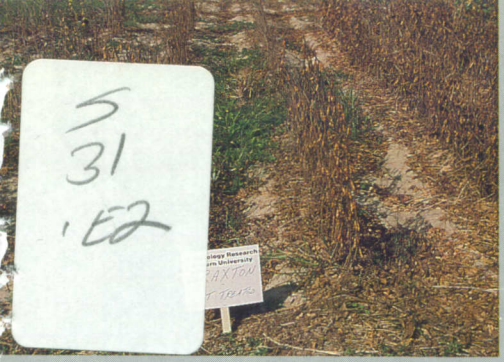

Performance of Soybean Cultivars in Fields Infested with Plant-Parasitic Nematodes in Alabama

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Lowell T. Frobish, Director
Auburn University
Auburn University, Alabama

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PERFORMANCE OF SOYBEAN CULTIVARS in Fields Infested with Plant-Parasitic Nematodes in Alabama[1]

R. RODRIGUEZ-KABANA, D.B. WEAVER, and E.L. CARDEN[2]

THE SOYBEAN [*Glycine max* (L.) Merr.] is subject to attack by several species of nematodes (*11*). Economically important species in Alabama are the soybean cyst nematode (SCN) (*Heterodera glycines* Ichinohe) and root-knot nematode (RKN), either the southern root-knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood] or the peanut root-knot nematode [*Meloidogyne arenaria* (Neal) Chitwood]. Of lesser economic importance are the lance nematode [*Hoplolaimus galeatus* (Cobb) Thorne], lesion nematode (*Pratylenchus* spp.), stubby-root nematode [*Paratrichodorus christie* (Allen and Sidiqi)], and spiral nematode [*Helicotylenchus dihystera* (Steiner) Andrassy]. Recent surveys in Alabama indicate that 29 percent of the soybean fields are infested with SCN and 23 percent with RKN; 10 percent are infested with both species. Approximately 15 percent of Alabama's soybeans are lost annually to nematode feeding (*7*), about half to SCN and half to RKN and other nematodes. Previous studies have shown that yields of all soybean cultivars respond to effective nematicide treatments in soils heavily infested with RKN (*3,6,8,12*), but usually only susceptible cultivars respond to nematicide treatments in soils infested with SCN alone (*1*).

The fumigant nematicides DBCP (1,2-dibromo-3-dichloropropane) and EDB (ethylene dibromide) are inexpensive, effective chemicals for nematode control on soybeans (*6*,12),

[1]This research was supported in part by a grant from Alabama Soybean Producers.
[2]Professor of Plant Pathology, Assistant Professor of Agronomy and Soils, and Superintendent of Gulf Coast Substation, respectively.

but recent action by the Environmental Protection Agency has prohibited their use. Although effective nematicides are available for nematode control in soybeans (*13*), they are often not economical to use, especially when soybean prices fall below $6 per bushel. Soybean producers must therefore rely on cropping sequences (rotation with nonhost crops) and genetic resistance as their primary means of nematode control. Recent studies have shown the advantages of crop rotation (*4,5*) for controlling *M. incognita* when resistant soybean cultivars are used in the rotation. In addition, there has been a large increase in the number of soybean cultivars available during the past 15 years, particularly proprietary cultivars (*2*). Even though cultivar performance tests are conducted yearly in Alabama, they are not conducted in areas of heavy nematode infestation.

Field experiments were conducted at three locations in Alabama with the following objectives: (1) determine the amount of recoverable soybean yield lost to nematodes in situations where more than one damaging species of nematodes are present, (2) determine relative resistance of soybean cultivars to mixed nematode populations, and (3) determine the effect of cultivar on final (harvest) nematode populations.

MATERIALS AND METHODS

A total of 19 field experiments was conducted during 1982-85 at three nematode-infested locations in Alabama. Seven cultivars were evaluated in each experiment with no nematicide (control) and 2 gallons per acre EDB applied at planting. The 14 treatments in each experiment were arranged in a 2 x 7 factorial structure in a randomized complete block design with eight replications. Plots were two rows 20 feet long end-trimmed at harvest to 16 feet, with spacings between rows of 30 to 40 inches depending on location. Planting dates ranged from May 15 to June 22. EDB was applied by two injectors 14 inches deep and 6 inches to each side of the row immediately before planting.

Soil samples for nematode analysis were collected when plants were at or nearing maturity. Samples consisted of a composite of 16 to 20 soil cores (each 1.0 inch in diameter) from each plot from the root zone to a depth of 8 to 10 inches. A subsample of approximately 6 cubic inches (100 cubic centimeters) of soil was used to determine total nematode

TABLE 1. MATURITY GROUP AND NEMATODE REACTIONS OF CULTIVARS AND GENETIC LINES EVALUATED WITH AND WITHOUT A NEMATICIDE IN FIELDS WITH VARIOUS NEMATODE POPULATIONS

Cultivar	Maturity group	Nematode reaction			
		M.i.[1]	M.a.	SCN (race 3)	SCN (race 4)
Asgrow A5474	V	S2	S	R	R
Bedford	V	R	MR	R	R
Deltapine 105	V	S	S	S	S
Epps	V	R	MR	R	R
Forrest	V	R	MR	R	S
Hartz 5370	V	R	S	R	S
Pioneer 9561	V	R	S	R	S
Pioneer 9571	V	R	MR	R	R
Asgrow A6520	VI	S	S	R	R
Centennial	VI	R	S	R	S
Davis	VI	S	S	S	S
GK 67	VI	R	S	S	S
Hartz 6383	VI	R	S	R	S
Jeff	VI	R	S	R	R
Leflore	VI	R	S	R	R
Northrup-King S69-96	VI	S	S	S	S
Terra-Vig 606	VI	R	R	S	S
Young	VI	S	S	S	S
Asgrow A7372	VII	R	S	S	S
Braxton	VII	R	R	S	S
Coker 627	VII	R	S	R	S
Coker 317	VII	S	MR	R	S
Deltapine 417	VII	R	S	S	S
Deltapine 497	VII	S	S	S	S
GK 49	VII	S	S	S	S
Gordon	VII	R	MR	R	S
Hartz 7126	VII	S	S	R	S
Ring Around RA 702	VII	R	S	R	S
Ransom	VII	S	S	S	S
Wright	VII	R	R	S	S
Cobb	VIII	R	S	S	S
Coker 368	VIII	R	S	R	S
Foster	VIII	R	S	R	S
Johnston	VIII	S	S	S	S
Kirby	VIII	R	R	R	S
Experimental genotypes					
Au82-2386	VII	R	R	S	S
F77-7142	VII	R	R	R	S
F81-2815	VII	R	S	R	S
F82-1739	VII	R	R	R	R
Ga80-1413	VII	R	S	R	S
N81-1756	VII	S	S	S	S
F80-3602	VII	R	R	R	S

[1] M.i. = *Meloidogyne incognita*, M.a. = *Meloidogyne arenaria*, SCN = soybean cyst nematode.

[2] R = resistant, MR = moderately resistant, S = susceptible.

numbers by the "salad bowl" incubation technique (*9*). Briefly, soil subsamples were wrapped in facial tissue paper (Scotties®) and submerged in water for a 72-hour incubation period. The water was then passed through a 400-mesh sieve and nematodes were counted.

The three locations were selected to represent certain nematode species and/or mixtures of species likely to be a problem in Alabama. Most of the experiments were conducted in a farmer's field in Baldwin County, near Elberta, on a Ruston loamy fine sand primarily infested with a mixture of RKN (*M. incognita)* and SCN (race 3). Experiments were also conducted at the Plant Breeding Unit, near Tallassee, on a Cahaba fine sandy loam, primarily infested with the "cotton complex" of nematodes: root knot (*M. incognita),* lance, stubby root nematodes, and lesion (*P. brachyurus)* nematodes. These species of nematodes tend to be present in fields that have a recent history of cotton production. The third location was at the E.V. Smith Research Center, near Shorter, on a Norfolk loamy sand primarily infested with SCN (race 3).

Cultivars and experimental lines were selected based on known genetic resistance to particular nematode species, table 1, or were included as checks because of no known nematode resistance (i.e. Ransom). These lines represent a wide range of available commercial and elite experimental germplasm. With the exception of the application of EDB, recommended production practices were followed at each location for fertility and weed control. Insects were controlled as needed. No attempts were made to control foliar diseases; however, these diseases were not considered a yield-limiting factor in any of the experiments. All data were analyzed following standard procedures for analysis of variance (ANOVA) and differences between means were separated using Fisher's least significant difference. Unless otherwise indicated, differences reported in the text were significant at the 5 percent probability level.

RESULTS AND DISCUSSION

Farmer's Field, Elberta

RKN larvae (*M. incognita*) occurred in large numbers in nonfumigated plots at Elberta in 1982, causing large yield losses, table 2. Smaller numbers of SCN (race 3) and stubby root nematodes were present. There was no interaction between nematicide treatment and cultivars for yield, indicating

TABLE 2. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1982

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
A7372	5.3	27.5	58	19	41	15	1	2
Coker 317	1.1	33.6	172	20	2	6	2	2
Agratech 67	5.7	28.1	132	49	0	1	3	4
RA 702	7.9	30.1	89	30	10	5	1	6
Braxton	8.4	33.8	85	7	5	51	2	2
Foster	12.2	37.3	189	9	2	2	1	3
Ransom	4.8	36.5	49	44	0	9	1	4
Mean	6.6	32.4	111	25	9	13	2	3
LSD (0.05)	5.6		58		NS		3	

that cultivars, regardless of their genetic resistance, responded similarly whether or not they were treated with nematicide. Plots that did not receive nematicide averaged 80 percent less yield than those treated with nematicide, and even the most resistant cultivar, Foster, suffered a yield loss of 67 percent. In 1983, with better rainfall, yields were higher in both fumigated and nonfumigated plots, table 3. Foster had significantly higher yields in nonfumigated plots than other cultivars. Conditions favorable for high yields also favored large nematode populations. RKN again occurred in large numbers, with SCN and stubby-root nematodes present. RKN numbers were highest on Foster, the most resistant cultivar, but this was because of time of sampling. Sampling was done after nematode populations had started to decline due to plant

TABLE 3. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1983

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
A7372	16.5	38.2	312	26	11	26	3	15
Coker 317	18.7	54.7	383	60	4	7	5	6
Agratech 67	14.8	38.2	338	36	16	22	4	11
RA 702	20.3	51.0	393	93	1	10	8	26
Braxton	22.4	42.7	213	69	17	44	7	9
Foster	30.0	56.6	454	37	2	19	3	7
Ransom	16.1	45.3	364	153	9	24	7	5
Mean	19.8	46.7	110	26	9	22	5	11
LSD (0.05)	7.8		134		17		7	

TABLE 4. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1983

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	21.4	45.9	86	34	12	22	2	6
Cobb	8.5	35.7	58	45	6	26	1	9
Coker 317	19.0	49.8	220	77	1	1	1	9
Foster	26.1	51.1	276	27	1	4	1	5
Johnston ...	8.5	40.1	143	33	30	33	0	5
Kirby	35.4	55.6	216	12	1	12	1	13
Ransom	14.5	41.5	110	34	1	14	3	9
Mean	19.1	45.7	158	37	7	16	1	8
LSD (0.05)	7.1		55		18		6	

death in the more susceptible cultivars, resulting in reduced populations on the susceptible ones. SCN populations tended to be higher in fumigated than in nonfumigated plots in both 1982 and 1983. This is probably due to the greater susceptibility of RKN to EDB, allowing better root growth and allowing SCN to compete more successfully for feeding sites in the fumigated plots. A second test was conducted on a different set of cultivars in 1983 with similar results, table 4. Seed yields and RKN numbers were high. Kirby, a nematode-resistant cultivar, had significantly higher seed yield than other cultivars in the nonfumigated plots. The interaction between cultivars and nematicide treatments for yield was not significant for either of the 1983 experiments. Yield reduction by nematode feeding was 58 percent (fumigated vs. nonfumi-

TABLE 5. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1984

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	2.0	27.3	214	127	277	249	4	12
Cobb	1.3	23.8	363	146	187	287	7	15
Coker 317	14.3	40.6	540	258	113	107	20	21
Foster	25.6	44.4	360	236	103	145	7	7
Johnston ...	3.8	30.3	276	86	201	257	9	20
Kirby	25.1	41.3	434	143	158	122	15	18
Ransom	5.0	29.1	331	186	205	225	11	16
Mean	11.0	33.8	360	169	178	199	10	16
LSD (0.05)	5.8		241		83		10	

gated) averaged for all cultivars across both experiments, but was only 36 percent for Kirby.

Favorable rainfall resulted in high yields in fumigated plots again in 1984, tables 5, 6, and 7. For the first time, SCN larval numbers became a significant factor, with populations almost as high as those for RKN. As a result, cultivars with good genetic resistance to both RKN and SCN in some cases produced yields in nonfumigated plots that were equal to those of susceptible cultivars in fumigated plots. Nematode feeding resulted in an average 65 percent yield loss. Leflore, with a high level of resistance, had a yield loss of 44 percent. Kirby was included in all 1984 experiments as a nematode-resistant check based on 1983 results, and had losses of 39, 51, and 47 percent. Ransom, included as a nematode-susceptible check

TABLE 6. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1984

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Coker 368	14.5	43.6	247	104	196	186	11	9
Forrest	10.9	35.1	255	113	149	141	10	12
Gordon	13.9	36.9	157	132	131	213	8	10
Kirby	19.4	39.3	196	128	170	135	4	11
Leflore	25.4	45.4	563	182	58	184	9	18
Ransom	6.7	29.7	215	103	202	360	8	8
Terra-Vig 606	9.7	34.5	243	193	200	334	8	8
Mean	14.4	37.8	268	136	150	222	8	11
LSD (0.05)	6.1		137		86		11	

TABLE 7. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1984

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	10.3	26.6	169	62	218	290	9	10
F77-7142	16.9	41.1	207	81	149	203	10	10
Foster	20.6	41.1	472	151	137	83	5	12
Kirby	19.4	36.9	267	87	153	142	5	11
N81-1756	4.2	24.2	385	79	163	301	3	11
Ransom	4.8	26.0	272	177	173	229	8	13
S69-96	3.0	30.3	252	144	125	235	6	10
Mean	11.3	32.3	289	112	160	212	7	11
LSD (0.05)	6.8		132		103		9	

TABLE 8. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Coker 368	10.2	25.1	112	10	58	108	22	8
Forrest	7.5	14.3	25	28	27	30	13	12
Gordon	8.8	19.7	49	22	48	51	14	12
Kirby	14.3	21.8	53	18	45	72	14	12
Leflore	17.7	29.9	220	29	14	18	16	4
Ransom	7.5	15.6	75	20	58	98	10	11
Terra-Vig 606	4.8	15.0	43	19	59	80	15	11
Mean	10.1	20.2	82	21	44	65	15	10
LSD (0.05)	4.7		51		40		11	

based on 1982 and 1983 results, had losses of 83, 77, and 82 percent. As in the two previous years, larval populations of SCN tended to increase in response to fumigation while those of RKN were reduced. Cultivar x fumigation treatment interactions were absent in 1985, except for the experiment summarized in table 6, which had a significant cultivar x fumigation treatment interaction for SCN numbers. Some cultivars showed no response to fumigation, while others showed larger SCN numbers in fumigated than control plots.

The shift toward dominance of SCN continued in 1985, tables 8, 9, 10, 11, 12, and 13, especially with cultivars that had no SCN resistance. Cultivars with SCN resistance tended to have more RKN than SCN larvae in nonfumigated plots, and more SCN than RKN in fumigated plots. SCN were

TABLE 9. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
A5474	10.2	23.1	80	35	13	23	2	5
Bedford	12.9	19.7	88	14	23	9	6	3
Deltapine 105	4.1	15.0	24	13	17	32	2	3
Epps	5.4	19.7	53	25	12	22	4	1
Hartz 5370 ...	10.2	22.4	45	18	9	12	1	5
Kirby	10.2	22.4	35	12	47	50	2	3
Ransom	3.4	19.0	69	27	32	78	2	4
Mean	8.1	20.2	56	21	22	28	3	3
LSD (0.05)	3.4		35		26		N.S.	

TABLE 10. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
A7372	0.7	4.8	59	12	47	164	8	20
Agratech 67	.0	4.8	62	5	47	134	4	29
Coker 317	8.8	29.2	212	71	82	139	13	23
Braxton	.7	4.1	44	16	46	72	9	23
Foster	4.8	19.0	89	10	49	98	13	18
RA 702	4.1	22.4	90	25	54	101	21	9
Ransom	2.0	17.0	92	25	77	164	15	18
Mean	3.0	14.5	93	23	57	125	12	20
LSD (0.05)	3.2		62		61		15	

TABLE 11. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	0.7	2.7	13	4	67	51	2	7
Cobb	.7	3.4	28	14	49	187	3	3
Coker 317	10.2	29.2	198	26	27	43	2	4
Foster	8.2	22.4	146	5	36	42	3	3
Johnston ...	1.4	11.6	37	21	69	112	2	4
Kirby	12.2	23.8	101	21	44	68	1	2
Ransom	4.1	15.6	76	17	59	102	3	4
Mean	5.4	15.5	86	15	50	86	2	4
LSD (0.05)	3.2		53		51		N.S.	

TABLE 12. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Centennial	3.4	21.1	41	7	57	42	11	3
Coker 627	4.1	21.1	69	9	32	35	3	8
Hartz 6383 ...	8.8	18.4	35	9	43	43	0	7
Jeff	6.1	21.1	68	9	10	11	4	4
Kirby	8.2	18.4	44	9	61	81	8	6
Pioneer 9571	10.2	15.6	66	8	3	11	3	7
Ransom	3.4	19.7	48	18	47	119	5	4
Mean	6.3	19.3	53	10	36	47	5	6
LSD (0.05)	3.8		28		26		N.S.	

TABLE 13. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT ELBERTA, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Root-knot larvae		Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Au82-2386	4.1	15.0	34	3	42	119	2	8
F80-3602 ..	11.6	23.8	52	15	54	105	7	10
F81-2815 ..	6.8	21.8	99	9	46	79	0	2
F82-1739 ..	15.6	27.9	107	13	20	28	2	9
Ga80-1413	9.5	24.5	106	21	23	51	4	5
Kirby	12.2	23.1	31	6	81	85	0	3
Ransom	7.5	17.7	55	8	53	87	1	2
Mean	9.6	22.0	69	11	47	79	2	6
LSD (0.05)	4.7		42		38		6	

apparently able to increase due to reduced competition from RKN in fumigated plots. There was also evidence of a shift in SCN population from race 3 to race 4. Cultivars with resistance to both SCN races, such as Leflore, Jeff, and Pioneer 9571, tended to have significantly lower numbers of SCN larvae than cultivars with resistance to SCN race 3 alone, tables 8 and 12. This greater SCN resistance did not result in significantly greater yield in nonfumigated plots, although Leflore tended to yield more. Interactions between cultivars and fumigation were much more prevalent in 1985 than in previous years. Significant interactions were found for RKN numbers, tables 8 and 11, SCN numbers, tables 11 and 12, and yield, tables 9, 10, 11, and 12. This was probably due to the increase in SCN numbers; no other variable was so markedly different from the previous years. While these interaction effects were significant, magnitude of the main effects (cultivars and fumigation treatments) mean squares was in most cases much larger than the magnitude of mean squares for the interactions, indicating that the main effects were relatively more important.

Plant Breeding Unit, Tallassee

In 1983 at Tallassee, lance, stubby-root, and spiral nematodes were present in the largest numbers, and lesion nematodes were also present, table 14. Fumigation did not decrease stubby-root nematodes, but significantly reduced lance and spiral nematodes. Even though yields were good in the control plots (31.5 bushels per acre), this was only 76 percent of the yield that was possible when nematodes were controlled

TABLE 14. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT PLANT BREEDING UNIT, 1983

Cultivar	Seed yield/acre		Nematodes/100 cc soil							
			Lance		Lesion		Stubby-root		Spiral	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	34.2	44.4	22	12	7	2	45	27	31	5
Centennial	33.4	42.7	31	5	6	1	28	25	20	2
Cobb	31.6	42.9	29	14	11	4	41	48	22	5
Davis	31.9	42.1	22	14	6	4	21	20	19	7
Forrest	26.2	37.3	27	9	8	6	18	22	15	8
Kirby	30.8	40.5	22	5	9	3	35	30	26	2
Ransom	32.3	41.9	15	8	7	1	33	42	17	4
Mean	31.5	41.7	24	10	8	3	32	31	21	5
LSD (0.05)	4.2		13		6		17		11	

TABLE 15. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT PLANT BREEDING UNIT, 1984

Cultivar	Seed yield/acre		Nematodes/100 cc soil							
			Lance		Lesion		Stubby-root		Spiral	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	42.2	50.3	22	3	11	5	21	43	17	2
Centennial	38.8	47.6	29	4	18	3	19	26	17	1
Cobb	40.8	46.2	22	3	6	1	27	51	24	3
Davis	42.2	46.2	17	6	6	2	21	32	28	5
Forrest	29.2	38.1	24	2	10	0	16	24	4	1
Kirby	36.0	41.5	13	4	11	3	22	22	16	2
Ransom	42.8	46.2	9	0	14	1	14	19	13	0
Mean	38.9	45.2	19	3	11	2	20	31	17	2
LSD (0.05)	4.3		12		7		18		12	

(41.7 bushels per acre in fumigated plots). Because population development of stubby-root nematodes was not controlled by fumigation, lance and/or spiral nematodes appeared to be the yield-limiting species in this environment. Consistent yield response of the cultivars to fumigation indicates little difference among cultivars for genetic resistance to lance or spiral nematodes.

Results were similar in 1984, table 15. Yields were generally higher and fumigation resulted in only a 14 percent yield increase, but nematode populations were similar to 1983 for all species. In 1985, spiral nematode numbers were insignificant, while lance and stubby-root nematodes continued to be the dominant species, table 16. Feeding by these species resulted in an average yield loss of 13 percent.

TABLE 16. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT PLANT BREEDING UNIT, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Lance		Lesion		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	37.4	41.5	18	3	7	0	10	9
Centennial	36.7	43.5	26	6	1	1	20	16
Cobb	39.4	46.9	15	4	5	1	14	19
Davis	38.1	40.1	18	8	13	1	24	22
Forrest	37.4	44.9	23	2	3	3	16	10
Kirby	35.4	38.8	11	2	5	0	15	15
Ransom	36.0	44.2	12	2	5	2	11	15
Mean	37.2	42.8	18	4	6	1	16	15
LSD (0.05)	3.8		8		4		9	

Two additional tests were conducted in a different field site at the Plant Breeding Unit in 1985. RKN (*M. incognita*) predominated at this site, along with significant numbers of lesion, stubby-root, and spiral nematodes, tables 17 and 18. Even though RKN numbers were relatively high, nematode feeding caused only about a 6 percent yield loss. With the exception of Leflore, cultivars were consistent in response to fumigation.

TABLE 17. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT PLANT BREEDING UNIT, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil							
			Root-knot larvae		Lesion		Stubby-root		Spiral	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Braxton	49.6	51.7	53	1	12	4	23	13	3	7
Gordon	45.6	49.0	63	8	12	4	11	8	9	3
Hartz 6383 ...	46.9	49.0	63	5	18	1	11	5	10	5
Jeff	41.5	45.6	30	6	25	1	14	4	9	4
Leflore	55.1	55.1	31	5	6	9	4	0	4	4
Wright	41.5	45.6	149	17	9	6	9	3	4	0
Young	42.8	46.2	66	11	19	6	6	5	3	2
Mean	46.1	48.9	65	8	14	4	11	5	6	4
LSD (0.05)	6.3		23		8		6		6	

TABLE 18. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT PLANT BREEDING UNIT, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil							
			Root-knot larvae		Stubby-root		Spiral		Lance	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Asgrow A7372	40.1	39.4	16	11	17	11	16	5	21	9
Braxton	44.2	46.2	12	9	43	14	20	15	37	5
Coker 627	41.5	48.3	6	4	30	22	20	1	20	6
Deltapine 417	35.4	38.8	8	0	19	9	11	1	18	9
Deltapine 497	40.8	44.2	36	5	37	22	21	6	37	16
Hartz 7126 ...	45.6	48.6	44	7	29	3	15	3	31	5
RA 702	32.0	32.0	11	1	17	15	4	5	19	4
Mean	39.9	42.5	19	5	27	14	15	5	26	8
LSD (0.05)	4.4		14		14		10		12	

E. V. Smith Research Center, Shorter

Because it was known prior to planting that SCN was the primary nematode species at this location, only cultivars with genetic resistance to SCN were planted, with the exception of Braxton which was included as an SCN-susceptible check. This had the effect of reducing SCN larval numbers in all plots except Braxton, tables 19 and 20. Fumigation with EDB had no effect on SCN numbers in either experiment. Response to fumigation was fairly consistent for resistant cultivars in the first experiment, table 19, generally about 8 bushels per acre. The exception was Leflore, which showed no response to fumigation; however, the cultivar x fumigation interaction was not significant for any of the variables in both experiments. Braxton did not respond to fumigation in one of the exper-

TABLE 19. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT E. V. SMITH RESEARCH CENTER, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil					
			Soybean cyst larvae		Stubby-root		Lesion	
	Control	Fumigated	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Asgrow A5474	32.0	43.5	8	19	11	11	0	1
Bedford	25.8	34.0	10	7	14	13	3	1
Braxton	14.3	14.3	22	57	9	11	12	1
Epps	24.5	33.3	5	9	11	9	3	1
Forrest	27.9	35.4	2	6	17	12	1	1
Leflore	25.2	27.9	8	8	9	15	5	0
Pioneer 9561	26.5	37.4	2	10	10	7	4	1
Mean	25.2	32.3	8	17	12	11	4	1
LSD (0.05)	6.5		21		N.S.		6	

TABLE 20. SEED YIELDS AND NEMATODE NUMBERS AT THE R6 REPRODUCTIVE STAGE FOR SOYBEANS TREATED WITH 0 AND 2 GALLONS PER ACRE EDB AT E. V. SMITH RESEARCH CENTER, 1985

Cultivar	Seed yield/acre		Nematodes/100 cc soil			
			Soybean cyst larvae		Stubby-root	
	Control	Fumigated	Control	Fumigated	Control	Fumigated
	Bu.	*Bu.*	*No.*	*No.*	*No.*	*No.*
Asgrow A652	27.2	31.3	3	3	11	3
Braxton	14.3	21.1	31	28	5	6
Centennial	26.5	35.4	9	8	4	8
Gordon	30.6	35.4	8	0	6	5
Hartz 6383	32.0	37.4	3	0	10	10
Hartz 7126	27.2	35.4	14	1	15	4
Jeff	30.6	29.2	1	3	11	3
Mean	26.9	32.2	10	6	9	6
LSD (0.05)	6.3		19		N.S.	

iments, table 19, but showed a large response in the other, table 20. Response of resistant cultivars was consistent, but somewhat less in the second experiment than in the first. Previous research has shown that some SCN-resistant cultivars do not respond to nematicide in SCN-infested soil (*1*). The fact that Leflore and Jeff, cultivars with resistance to both SCN races 3 and 4, did not respond to nematicide might indicate the presence of SCN race 4, but other SCN race 3 and 4-resistant cultivars (A5474, Bedford, and Epps) showed large yield responses to nematicide. The possibility that this field could be infested with race 5 is unlikely because this was the first year SCN-resistant soybeans were grown.

SUMMARY

The three test locations represent very different situations with regards to endemic nematode populations. Elberta has probably the worst situation, where both RKN and SCN occur in large numbers. Economic yields probably cannot be made under these circumstances without a nematicide even with the most resistant cultivar. However, the effects of the nematicide and genetic resistance were generally additive, as evidenced by the general lack of a significant cultivar x nematicide treatment interaction for seed yield. Highest yields were generally obtained with cultivars that had the broadest spectrum of nematode resistance, regardless of nematicide treatment. For example, Leflore, which has resistance to both species of RKN as well as to SCN races 3 and 4, was the high-yielding cultivar in both fumigated and nonfumigated plots in 1984 and 1985, tables 6 and 8. Kirby and Foster, other cultivars with resistance to multiple nematode species, also performed well. Braxton and Cobb, however, which have resistance only to RKN, did not yield more than Ransom, which has no nematode resistance, tables 5, 10, and 11.

Use of RKN-resistant cultivars did not result in lower RKN numbers at harvest; in fact, the opposite occurred. Leflore, Foster, and Kirby tended to support RKN populations as high or higher than RKN-susceptible cultivars. This can be partially explained by the fact that in nonfumigated plots, nematode feeding often caused RKN-susceptible cultivars to die well before normal harvest dates. Thus when the plots were sampled, nematode populations in these plots had already started

to decline. However, RKN-resistant cultivars continued to grow, produce roots, and supported ever-increasing RKN populations. It had been previously shown (*10*) that RKN populations developed more slowly on resistant cultivars, but such varieties were able to support as many or more RKN as susceptible cultivars. Thus, use of RKN-resistant cultivars is not a good strategy for reducing RKN numbers.

SCN, which occurred in low numbers in 1982 and increased somewhat in 1983, became a major problem in 1984. Fumigation generally increased SCN numbers due to a combination of less susceptibility of SCN to EDB, more root growth in EDB-treated plots, and less competition from RKN. SCN-resistant cultivars usually had significantly lower SCN numbers than SCN-susceptible cultivars, especially in fumigated plots. Again, SCN numbers on susceptible cultivars were probably not as high at sampling as they were at their peak because of early plant death in many plots.

At the Plant Breeding Unit, where SCN did not occur, yields on nonfumigated plots were good while yield response to fumigation was relatively small. In nonfumigated plots, cultivars tended to yield similarly regardless of nematode resistance, except for Forrest, which probably yielded less because of its earlier (maturity group V) maturity. Thus, choice of cultivar did not influence performance at that location nearly so much as at Elberta. Although use of a nematicide may not be economically feasible in this situation, in almost every case cultivars responded positively to fumigation (average increase = 6 bushels per acre). Nematodes did not occur in high numbers, and plants in all plots appeared to be healthy with no symptoms of nematode damage. Yet, nematode feeding reduced yields an average 5.5 bushels per acre across experiments and years compared to fumigated plots. This demonstrates that soybeans that appear to be healthy can still suffer significant "hidden" yield losses from nematode damage.

At the E. V. Smith Research Center, resistant cultivars yielded well and reduced SCN numbers significantly in nonfumigated plots compared to susceptible Braxton, and fumigation resulted in an average yield response of 6.6 bushels per acre for the resistant cultivars. Susceptible Braxton averaged only a 3.4-bushel per acre response to EDB fumigation, indicating that it is not always possible to grow a susceptible

variety and attempt to control soybean cyst nematodes with chemicals.

Several conclusions can be drawn from these results:

1. Where large populations of RKN and SCN exist together, highest yields are possible only by growing a cultivar with a broad spectrum of nematode resistance together with using an effective nematicide. In general, planting a susceptible cultivar and using a nematicide is no better than planting a resistant cultivar.

2. Where RKN and other plant-parasitic nematode species exist in low numbers, plants can often suffer yield loss without visible symptoms of nematode feeding. Inclusion of a nematicide or other nematode control measure may increase yields, but economics of nematode control will largely be dictated by crop value.

3. Where SCN is the primary nematode species, use of resistant cultivars is an effective method of nematode control, and small additional yield gains can be realized by applying an effective nematicide. Again, economics of nematicide usage in this situation will be dictated by crop value.

These experiments have examined only two aspects of plant-parasitic nematode management in soybean: resistant varieties and nematicide use. The nematicide used in these experiments (EDB) has been banned by EPA action. Other alternative nematicides may or may not provide the same degree of control. Inclusion of management practices, particularly rotation with nonhost crops, and for SCN, rotations involving susceptible and resistant varieties to stabilize populations, may enhance productivity.

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