Effects of Continuous Culture of Resistant Soybean Cultivars on Soybean Cyst Nematode Reproduction

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ABSTRACT

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Soybean cyst nematode (SCN) populations were evaluated from 17 commercial fields in which a cultivar resistant to SCN races 3 and 4 had been grown continuously for 3–6 yr. Index of parasitism (IP, number of cysts on a soybean line relative to 100 on Essex) values for SCN reproduction ranging from 38 to 70 were obtained when the resistant cultivar Bedford was grown in infested soil for 30 days. Seed yields of resistant cultivars grown in these fields have not declined measurably. These results may be compared with those from an earlier study in which Bedford, grown for the first time in soil infested with SCN race 4, had an IP value of 32 when compared with three susceptible cultivars but gave no yield response from application of nematicides. Significantly less reproduction occurred on soybean strains J74-88, PI 89772, and PI 90763 than on Bedford; reproduction on Peking, D72-8927, PI 88788, and PI 209332 was intermediate and varied among SCN populations. Reproduction of these SCN populations on the soybean strains was similar to that obtained from recent greenhouse selection experiments involving the soybeans grown in SCN race 4 soil.

Additional key words: races, resistance

The soybean cyst nematode (SCN) (*Heterodera glycines* Ichinohe) infests about 20% of the acreage used for soybean (*Glycine max* (L.) Merr.) production in the United States. Four races of the nematode were designated in 1970 (3), although more variability has been reported (5,6,8,10,11,13). Resistant cultivars have played a major role in soybean production programs where SCN causes reduction in seed yield. Forrest, a cultivar resistant to SCN races 1 and 3, released in 1972, was estimated to prevent yield losses worth $400 million for the period 1975–1980. Bedford, a cultivar (4) resistant to races 3 and 4, released in 1977, was estimated to be grown on about 3 million acres in 1980. In a 3-yr study conducted by Epps et al (2) in soils infested with SCN race 4, Bedford produced a mean seed yield of 2,960 kg/ha, which was 32% greater than the mean seed yield of three cultivars susceptible to SCN race 4. Seed yield of Bedford was not increased by use of DBCP, ethoprop, or phenamiphos. Cyst count in Bedford plots was 90/250 cm^3 of soil compared with 277/250 cm^3 for the three susceptible cultivars. Bedford has continued to produce satisfactorily in the area where SCN race 4 was a problem. In several cases, it has been grown continuously since seed became available.

This study evaluated SCN biotypes in fields where soybean cultivars with the Bedford type of resistance had been grown for 3–6 yr.

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MATERIALS AND METHODS

About 10 L of soil was collected within a 1-ha area of soybean fields that had been planted to cultivars resistant to SCN race 4 for at least 3 yr. Four fields were sampled yearly during 1980–1982; two fields were sampled twice during this period, one field in 1980 and 1981 and the other in 1980 and 1982. In each of these fields, SCN race 4 was causing severe reduction in seed yield before Bedford was planted. In 1983, cooperative extension personnel in western Tennessee submitted about 10 L of soil from each of 11 additional fields where cultivars resistant to SCN race 4 had been grown for at least 3 yr. Soil was collected from each field between late August and early November.

Soil from each field was passed through a sieve with 6-mm apertures to remove debris, then it was mixed and placed in 7.5-cm-diameter clay pots. Each pot was planted with two seeds of a soybean strain. Each of 10 soybean strains was planted in either four or five pots (replicates), depending on amount of soil in the sample. Essex is considered susceptible to all SCN populations. Forrest is resistant to SCN races 1 and 3 and derives its resistance from Peking. Bedford derives resistance to races 3 and 4 from Forrest and PI 88788. PI 88788 is resistant to SCN races 1 and 3 and is the source for race 4 resistance even though it was designated susceptible in 1970 (3). D72-8927 derives resistance to races 1 and 3 and a Virginia race 2 population from Peking and PI 90763. PI 90763 is resistant to SCN races 1, 2, and 3. J74-88 derives resistance to races 3 and 4 from Forrest and PI 89772. PI 209332 is resistant to races 3 and 4. The pots were randomized for each field in a complete block design. Plants were grown in a greenhouse for 30 days at 28 ± 7 C, after which SCN females washed from the soil and roots were collected on a sieve with 250-μm apertures and counted.

Fields were divided into three groups based on the number of years sampled. Data were analyzed using a nonparametric rank test and means were separated by the Waller-Duncan k-ratio t test. Using the means, an index of parasitism (IP) was calculated as a standard for expressing resistance. IP = (number of females developing on a strain ÷ number of females on Essex) ×100. IP was used because race determinations are based on the number of SCN females or cysts developing on a differential soybean strain compared with the number developing on a susceptible strain (Essex). According to 1970 standards (3), a soybean strain is resistant if the IP is <10. The IP also compensates for the variability of cysts developing on soybean strains among different SCN populations

Table 1. Mean number of soybean cyst nematode females that developed on nine soybean strains when planted in individual soil samples from 11 fields that had been planted to cultivars resistant to SCN race 4 for at least 3 yr

Soybean strain	Mean no. females	IP[y]
Essex	299 a[z]	100
Forrest	204 b	68
Bedford	150 c	50
PI 209332	85 d	29
Peking	68 de	23
PI 88788	65 e	22
PI 90763	19 f	6
J74-88	15 f	5
PI 89772	14 f	5

[y] IP = (no. females on soybean ÷ no. females on Essex) × 100.

[z] Analysis was done on rank-tranformed data; means followed by the same letter do not differ significantly (P = 0.05) by Waller-Duncan k-ratio t test.

Table 2. Mean number of soybean cyst nematode females developing on 10 soybean strains when planted in soil sampled from four fields that had been planted to cultivars resistant to SCN race 4 for 3–6 yr

1980			1981			1982		
Soybean strain	Mean no. females	IP[y]	Soybean strain	Mean no. females	IP	Soybean strain	Mean no. females	IP
Essex	106 a[z]	100	Essex	199 a	100	Essex	442 a	100
Forrest	97 a	91	Forrest	197 a	99	Forrest	297 b	67
Bedford	74 a	70	Bedford	140 b	70	Bedford	258 b	58
Peking	32 b	30	PI 209332	97 c	49	PI 88788	156 c	35
PI 209332	28 bc	26	D72-8927	53 d	27	PI 209332	139 c	31
PI 88788	22 c	21	PI 88788	51 d	26	D72-8927	109 d	25
D72-8927	21 c	20	Peking	30 e	15	Peking	73 e	17
PI 90763	6 d	6	PI 90763	10 f	5	J74-88	33 f	7
PI 89772	6 d	6	PI 89772	10 f	5	PI 90763	27 fg	6
J74-88	5 d	5	J74-88	4 g	2	PI 89772	18 g	4

[y] IP = (no. females on soybean ÷ no. females on Essex) × 100.
[z] Analysis was done on rank-transformed data; means followed by the same letter do not differ significantly ($P = 0.05$) by Waller-Duncan k-ratio t test.

Table 3. Mean number of soybean cyst nematode females developing on 10 soybean strains when planted in soil sampled from two fields that had been planted to cultivars resistant to SCN race 4 for 3–6 yr

Soybean strain	Mean no. females	IP[y]	Soybean strain	Mean no. females	IP
Prather field, 1980			**Prather field, 1982**		
Essex	185 a[z]	100	Essex	297 a	100
Bedford	71 a	38	Forrest	262 ab	88
PI 88788	41 ab	22	Bedford	204 ab	67
PI 209332	34 b	18	PI 209332	139 bc	47
Forrest	2 c	1	PI 88788	126 c	42
D72-8927	1 cd	1	Peking	102 cd	34
J74-88	1 cd	0	D72-8927	51 de	17
Peking	0 d	0	PI 89772	45 ef	15
PI 89772	0 d	0	PI 90763	25 ef	8
PI 90763	0 d	0	J74-88	18 f	6
Southall field, 1980			**Southall field, 1981**		
Essex	16 a	100	Essex	180 a	100
Forrest	11 ab	69	Forrest	90 ab	50
Bedford	9 bc	56	Bedford	87 bc	48
D72-8927	6 bc	39	D72-8927	49 cd	27
Peking	5 bcd	34	PI 209332	42 cd	23
PI 209332	3 cde	21	PI 88788	22 d	12
PI 88788	2 de	11	Peking	22 d	12
J74-88	1 de	6	PI 90763	4 e	3
PI 89772	1 de	6	J74-88	4 e	2
PI 90763	1 e	3	PI 89772	3 e	2

[y] IP = (no. females on soybean ÷ no. females on Essex) × 100.
[z] Analysis was done on rank-transformed data; means followed by the same letter do not differ significantly ($P = 0.05$) by Waller-Duncan k-ratio t test.

caused by nematode density or other factors.

RESULTS AND DISCUSSION

The number of cysts in the soil at planting ranged from 0 to 350/450 cm^3 soil. The IP for Bedford in this study ranged from 13 to 99. The field with the IP of 13 had been planted to cultivars resistant to SCN race 4 for 5 yr and only a few cysts with very few eggs in them were found in the soil when the test was planted. The field with the IP of 99 for Bedford had been planted to resistant cultivars for 4 yr and had 85 cysts per 450 cm^3. The field with 350 cysts per 450 cm^3 soil had an IP of 60 for Bedford and had been planted to cultivars resistant to race 4 for 4 yr.

Because year × soybean strain interaction was significant, data is presented as a summary of fields by year (Tables 1 and 2). Essex, Forrest, and Bedford all had IPs ≥50, and significantly more females developed on these three strains than on any of the other soybean strains. The number of females developing on Bedford was often significantly less than the number on Essex. J74-88, PI 89772, and PI 90763 had IPs <10, and the number of females developing on these strains was significantly less than the number of females on Bedford. Four strains (D72-8927 was deleted from data analysis in Table 1 because of poor seed germination) had IPs between 15 and 50 and their rank positions were not always the same. Data for the Southall and Prather fields sampled for 2 yr are presented in Table 3. It is difficult to interpret the 1980 Southall population data because of low nematode reproduction. Low reproduction of the 1980 Prather field population on Forrest was inconsistent with the reproduction of any other population on Forrest. The 1981 and 1982 results for these fields are consistent with the data presented in Tables 1 and 2.

Results of this study support those of greenhouse experiments in which reproduction rate of SCN populations on resistant germ plasm increased after continuous exposure of nematodes to resistant germ plasm (7,9,12,14). Nematode populations were selected that could reproduce well on Essex, Forrest, Bedford, Peking, PI 88788, PI 89772, and PI 90763 from within three SCN race 4 field populations (14). When nematode populations reproduced well on Bedford, they reproduced significantly less on PI 89772 and PI 90763. Because J74-88 derives part of its resistance from PI 89772, it is consistent for this strain to be resistant to field populations in this study. D72-8927 and J74-88 are being used to develop productive soybean germ plasm resistant to a broad range of SCN populations, including the TN-79 population (13). Some of this germ plasm may be resistant to SCN populations, which can reduce yield of Bedford and/or other cultivars resistant to SCN race 4.

It may appear from these data that SCN race 4 resistance has failed; however, that conclusion is inconsistent with results from field studies and observations. Bedford commonly has an IP >10 for SCN race 4 field populations and yields 20% or more than susceptible cultivars do. Using SCN cyst densities sampled 60–90 days after planting cultivars in fields infested with SCN race 4 in place of the greenhouse test to calculate the IP, Bedford had an IP of 32 in the study conducted by Epps et al (2). D77-5090 and D77-5169, two soybean strains with the Bedford type of SCN race 4 resistance, had 2-yr mean IPs of 39 and 34, respectively. Their seed yields were 144 and 146% (significant at $P = 0.05$), respectively, of that of Essex when grown in fields not subjected to continuous cropping of cultivars resistant to race 4. Growers have reported that soybean yields in fields listed in Table 2 have not

declined even though the IP is >50 (1). Nematode densities for these four fields were 35–145 cysts per 450 cm^3 soil in 1982. Lack of yield reduction in these fields with IPs >50 is in accordance with a field study.

After 4 yr of planting Bedford in the same plots, yield had not declined, although the IP (using the 30-day greenhouse test) rose from 15 to 86. Cyst populations at harvest increased from 94 to 130/450 cm^3 soil for Bedford plots and populations in plots cropped continuously to a susceptible cultivar increased from 364 to 383 cysts per 450 cm^3 soil. After the fourth year, Bedford seed yield was 123% of the yield of the susceptible cultivar (significant at $P=0.05$). In another study in plots that represented 7 yr of continuous Bedford, the IP was 43 and seed yield was 110% of that of Essex (significant at $P=0.05$) plots where Essex had been grown for 2 yr following 5 yr of Bedford. There were 157 cysts per 450 cm^3 soil in Bedford plots compared with 390 cysts per 450 cm^3 in Essex plots.

Although the nematode has responded to selection pressure from continuous cropping of resistant cultivars, population densities seem to remain below an economic injury level for cultivars resistant to SCN race 4. It is difficult to predict from the data presented whether SCN biotypes now present in the fields sampled will increase to levels causing economic injury to cultivars with the Bedford type of SCN resistance. However, germ plasm that appears to have a very high level of resistance to these SCN biotypes has been identified and is being used in a breeding program.

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