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Assessing *Heterodera glycines*-Resistant and Susceptible Cultivar Yield Response

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Abstract: The soybean cyst nematode *Heterodera glycines* (SCN) is of major economic importance and widely distributed throughout soybean production regions of the United States where different maturity groups with the same sources of SCN resistance are grown. The objective of this study was to assess SCN-resistant and -susceptible soybean yield responses in infested soils across the north-central region. In 1994 and 1995, eight SCN-resistant and eight SCN-susceptible public soybean cultivars representing maturity groups (MG) I to IV were planted in 63 fields, either infested or noninfested, in 10 states in the north-central United States. Soil samples were taken to determine initial SCN population density and race, and soil classification. Data were grouped for analysis by adaptation based on MG zones. Soybean yields were 658 to 3,840 kg/ha across the sites. Soybean cyst nematode-resistant cultivars yielded better at SCN-infested sites but lost this superiority to susceptible soybean cultivars at noninfested sites. Interactions were observed among initial SCN population density, cultivar, and location. This study showed that no region-wide predictive equations could be developed for yield loss based on initial nematode populations in the soil and that yield loss due to SCN in our region was greatly confounded by other stress factors, which included temperature and moisture extremes.

Key words: crop loss, crop rotation, *Glycine max*, *Heterodera glycines*, management, resistance, soybean, soybean cyst nematode, yield, soil type.

The soybean cyst nematode *Heterodera glycines* (SCN) is widely distributed throughout the north-central United States where different maturity groups with the same source of SCN resistance are grown (Riggs, 2004; Anonymous, 2005). State surveys in the region report from 14% to 63% of fields are infested with SCN (Niblack et al., 1993; Willson et al., 1996). A survey of researchers and extension personnel in the northern soybean-growing regions estimate the numbers of soil samples processed annually for SCN to be between 30 and 10,000, which is estimated to be approximately 3% to 70% of the sampling that needs to be conducted in the northern region to determine the level of SCN infestation in soybean production fields and to address implementation of management strategies (Hershman and Bond, 2002). The impact of SCN on soybean yield is significant. Up to 30% yield loss has been observed in areas of fields heavily infested with SCN without differences in plant height between susceptible and resistant cultivars or chlorosis (Niblack et al., 2004). In the north-central United States, SCN is the single largest contributor to yield loss due to disease, with an estimated loss of more than 1.3 million metric tons annually between 1989 and 1991 (Doupnik, 1993). Wrather et al. (2003) have documented past and current yield losses due to this nematode pest.

Management of SCN includes rotation to nonhost crops such as alfalfa (*Medicago sativum* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.), and planting of SCN-resistant soybean cultivars (Niblack, 1999). Measurable yield improvement can be realized when resistant cultivars are used in SCN-infested fields, especially as SCN population density at planting increases (Young, 1996; Wheeler et al., 1997; Chen et al., 2001a). In spite of reduced nematode reproduction, resistant cultivars do not prevent root penetration and associated stresses on the plant (Chen et al., 2001b). Optimization of the planting of resistant cultivars requires reducing the level of infective juveniles in highly infested fields. Additionally, continued planting of the same resistant cultivar encourages selection for populations with increased virulence on those cultivars (Noel and Edwards, 1996; Young, 1998).

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Crop damage as measured by reduction in yield varies with the environment, as do the detectable aboveground symptoms of nematode infestation (Noel and Edwards, 1996; Young, 1996; Niblack et al., 2004). If nematode damage is measured only as loss in yield and environmental effects play a major role in determining yield, the cause-and-effect relationship between presence of SCN and crop loss can be hard to establish. Ideally, inoculum potential as measured by the number of eggs present in the soil at planting would be a good predictor of varietal performance. The objective of this study was to test the hypothesis that cultivars would respond similarly to SCN across the north-central United States and a model could be developed to predict the relationship between yield and SCN.

Materials and Methods

Establishment of research plots: A 2-yr cooperative regional project on the effect of SCN resistance in soybean was conducted in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin in 1994 and in 1995. Soybean cyst nematode reproduction data from this study were reported earlier (Wang et al., 2000). In each state, experimental plots were established at a minimum of two SCN-infested sites and one site that was either noninfested or infested with a low population density of SCN. Four replicate plots for each of eight selected SCN-resistant and eight susceptible cultivars (Table 1) were planted in a randomized complete block design at each location. Planting dates varied but were appropriate for commercial soybean production at each location. Individual plots consisted of four 6-m-long rows spaced 76 cm apart. Soil sampling, cyst extraction, and egg staining protocol were described previously (Wang et al., 2000). Race determination data were reported previously (Wang et al., 2000). At harvest, the center two rows were trimmed to 5 m and harvested. Grain yields were adjusted to 13% moisture.

Table 1. Cultivars planted at each site in 1994 and 1995 in north-central United States, maturity group, SCN reaction, and source of resistance.

Cultivar	MG	SCN reaction	Source of SCN resistance
AP1991	I	Resistant	Peking
Bell	I	Resistant	‘PI88788’
Parker	I	Susceptible	
Sturdy	I	Susceptible	
Jack	II	Resistant	‘PI88788’
Newton	II	Resistant	Peking
Corsoy79	II	Susceptible	
Kenwood	II	Susceptible	
Linford	III	Resistant	‘PI88788’
MFA9043[a]	III	Resistant	Peking
Resnik	III	Susceptible	
Williams82	III	Susceptible	
Delsoy4210	IV	Resistant	‘PI88788’
Pharaoh	IV	Resistant	Peking
Flyer	IV	Susceptible	
Spenser	IV	Susceptible	

[a] In 1995, MFA9345, a sister-line, was substituted due to poor germination and seedling vigor of MFA9043.

The soil remaining after the subsamples for nematode analysis were removed from each site was bulked by location for soil analysis. Textural analysis as determined by Belmond Labs, Belmond, IA, is reported in Table 2.

Bioassays were used to confirm non-SCN-infested sites. Seven-d-old seedlings of ‘Corsoy79’ were transplanted into 150 cm^3 of soil in 9-cm-diam. pots, and plants were grown at 25 °C for 28 d. Roots were removed carefully from the soil, washed gently, and examined for the presence of females. If no females were observed on the roots during visual examination, roots were washed with a high-pressure water stream and the washings collected on a 250-µm-pore sieve and examined for presence of females using a stereomicroscope.

Assessment of resistant vs. susceptible cultivar: To assess the mean yield differences between resistant and susceptible classes of cultivars of similar maturity across a broad range of SCN-infested and noninfested environments, data were divided into four parts: Early, full-season north, full-season south, and late, based on the maturity adaptation of the cultivars for the site at which they were grown. Each site was classified as maturity zone (MZ) I, II, III, or IV, based on MG considered appropriate for production of a full-season cultivar at that site. Tests in which the MG of the cultivars was one group earlier than full-season were considered early-season tests. Those tests in which the MG of the cultivars was one group later than full-season were considered late-season tests. Full-season tests were divided into north (MG I and II) and south (MG III and IV) to account for potential differences in determinant or indeterminant cultivars and their impact on nematode populations. Cultivars that were more than one MG earlier or later than full-season cultivars were excluded from yield analysis for adapted cultivars.

The four data sets (early, full north, full south, and late) were analyzed separately. Sites were classified by infestation class (i.e., infested or noninfested) and for productivity based on site mean yield obtained in this study. A low mean yield was less than 1,600 kg/ha, medium was 1,600 to 2,400 kg/ha, and high was greater than 2,400 kg/ha. Data were collected over multiple years at the multiple locations to examine a wide range of yield environments. Classification for productivity was included to standardize sites and to test environmental and nematode interactions involving productivity levels. This classification was partially confounded with year when marginal soil and/or moisture had a greater impact on yield than soybean cyst nematode population density. Of the 21 sites of low productivity, 20 occurred in 1995, and 18 of the 22 high-productivity sites occurred in 1994 (Table 3).

TABLE 2. Location, maturity group zone, soybean cyst nematode race, soil texture, and estimate of SCN population density at planting (Pi) of the north-central United States SCN project test sites in 1994 and 1995.

	1994			
Location	MG zone[a]	SCN race	Soil texture[b]	Average Pi[c]
Hancock, WI	I	3	sand	4,300
St. Charles, MI	I	3	sandy loam	3,500
Jackson, MN	I	9	loam	1,200
Hancock, WI	I	—	sand	NI[d]
Rosemont, MN	I	—	silt loam	NI[d]
Kanawha, IA	II	1	clay loam	—
Ames, IA	II	3	clay loam	4,000
Kanawha, IA	II	3	clay loam	1,300
Racine, WI	II	3	clay loam	2,400
Renville, MN	II	3	clay loam	500
Lansing, MI	II	—	sandy loam	NI[d]
Crawfordsville, IA	II	—	clay loam	500
Romney, IN	III	1	silt loam	1,000
Edina, MO	III	3	silt loam	2,300
Effingham, IL	III	3	silt loam	—
High Hill, MO	III	3	silt loam	2,100
Lafayette, IN	III	3	silt loam	500
Tekamah, NE	III	3	clay loam	5,100
Tekamah, NE	III	3	loam	5,500
Champaign, IL	III	9	silt loam	900
Bucyrus, OH	III	14	silt clay loam	8,500
Champaign, IL	III	14	loam	300
Mt. Sterling, OH	III	14	clay loam	4,000
London, OH	III	—	silt clay	NI[d]
Mead, NE	III	—	silt loam	NI[d]
Romney, IN	III	—	clay loam	NI[d]
Severance, KS	IV	3	silt loam	400
Powhattan, KS	IV	—	silt clay loam	NI[d]
Columbus, KS	V	3	loam	1,500

TABLE 2. *Continued*

	1995			
Location	MG Zone[a]	SCN race	Soil texture[b]	Average Pi
Hancock, WI	I	3	loamy sand	
Sacred Heart, MN	I	3	clay loam	600
St. Charles, MI	I	3	sandy loam	5,700
St. Charles, MI	I	3	sandy loam	4,100
Hancock, WI	I	—	loamy sand	NI[d]
Rosemont, MN	I	—	silt loam	NI[d]
Kanawha, IA	II	1	clay loam	—
Ames, IA	II	3	clay loam	2,200
Jerry City, OH	II	3	sandy loam	4,400
Kanawha, IA	II	1	clay loam	3,200
Lake Crystal, MN	II	3	clay loam	800
Muscatine, IA	II	3	loamy sand	10,100
Muscatine, IA	II	3	sand	—
Racine, WI	II	3	clay loam	1,200
Dwight, IL	II	5	loam	1,700
Ames, IA	II	—	clay loam	—
Romney, IN	III	1	loam	6,000
Benton City, MO	III	3	silt loam	5,900
Champaign, IL	III	3	silt loam	200
Edina, MO	III	3	silt loam	6,100
Klondike, IN	III	3	silt loam	—
Newton, IL	III	3	loam	29,800
Tekamah, NE	III	3	silty clay loam	10,100
Tekamah, NE	III	3	loam	15,200
West Milton, OH	III	3	clay loam	13,700
Grand Pass, MO	III	—	silt loam	NI[d]
Mead, NE	III	—	silt loam	NI[d]
Romney, IN	III	—	silt loam	NI[d]
South Charleston, OH	III	—	silt loam	NI[d]
Rossville, KS	IV	4	sandy loam	12,000
Manhattan, KS	IV	—	silt loam	NI[d]
Columbus, KS	V	3	silt loam	4,800

[a] Maturity group zone defined by researchers in each state.

[b] Determined from bulked sample of remnant soil. Soil classifications were all conducted by Belmond Labs, Belmond, IA.

[c] Number of eggs/100 cm^3 soil.

[d] Not infested, confirmed by bioassay.

Cultivars were classified into one of two resistance classes (i.e., resistant or susceptible).

The dependent variable for analysis was yield. There were three or four replicates at each site. Infestation classes, levels of productivity, and resistance classes were considered fixed effects, whereas sites and cultivars were considered random effects. The rationale for considering cultivars random was to extend the scope of inference to the population of all available resistant and susceptible cultivars. Considering cultivars random provides a conservative error term for comparisons between resistant and susceptible classes. See Table 4 for analysis of variance table for the model used in this data analysis.

Mixed-model equations were solved using the general linear mixed models software with the data collected in this study (Blouin et al., 1989). The restricted maximum likelihood method (REML) was used to solve for variance components.

Effect of initial nematode population on yield: The effect of initial nematode population (Pi) on cultivar yield was evaluated for each cultivar across three MG zones: full-season, early-season, and late-season. Initial nematode population (Pi) was measured as nematode eggs per 100 cm^3 of soil and was transformed by a $\log_{10}$(Pi+1) transformation. The general linear model procedure of SAS (SAS Institute, Cary, NC) was used with $\log_{10}$(Pi+1) as a covariable.

RESULTS

Experimental sites: Thirty-two and 34 sites were planted, and 30 and 33 sites were harvested in 1994 and 1995, respectively. Table 2 lists the sites harvested in 1994 and 1995, their location and maturity group zone, SCN race present, soil textural class, and mean Pi. Of the 63 sites, 14 were noninfested; 33 were infested with SCN race 3; six sites with SCN races 1 or 5, which will reproduce on PI 88788 sources of resistance; five sites with SCN races 9 or 14, which will reproduce on Peking sources of resistance; and one site with race 4, which

TABLE 3. Grain yield of SCN-resistant and -susceptible soybean cultivars by north-central U.S. location averaged across maturity groups.[a]

	Average grain yield kg/ha			Cultivar comparison	
Location	Resistant	Susceptible	Difference	LSD	Prob 0.05
		1994			
IL-1 Champaign	2,381	2,217	163.5	270.6	0.20
IL-2 Champaign	2,216	1,997	218.6	443.6	0.29
IL-3[b] Effingham	3,101	3,282	–180.4	669.8	0.55
IN-1 Lafayette	3,899	3,745	154.7	731.6	0.63
IN-2 Romney	2,976	2,701	275.0	465.1	0.20
IN-3[b] Romney	3,618	4,052	–434.1	523.1	0.09
IA-1 Kanawha	2,270	1,799	470.8	602.3	0.11
IA-2 Crawfordsville	3,219	3,036	182.5	592.8	0.48
IA-3 Ames	3,776	2,777	998.9	526.3	0.00
IA-4[b] Kanawha	2,883	2,848	34.9	703.9	0.91
IA-5[b] Crawfordsville	3,480	4,570	–1,089.7	2,738.5	0.38
KS-1 Severance	2,495	2,521	–26.8	301.4	0.84
KS-2 Columbus	1,798	1,258	540.3	181.0	0.00
KS-3[b] Powhattan	2,201	2,493	–291.9	296.2	0.05
MI-2 St. Charles	1,932	1,704	228.3	379.6	0.20
MI-3[b] Lansing	2,474	2,780	–306.0	570.6	0.25
MN-1 Renville	3,396	3,094	302.0	820.5	0.37
MN-2 Jackson	3,150	2,547	604.0	670.6	0.07
MN-3[b] Rosemont	3266	3521	–255.4	805.8	0.43
MO-2 Edina	10,370	2,885	7,484.6	15,118.1	0.33
MO-3[b] High Hill	1,625	1,640	–14.1	263.7	0.91
NE-1 Tekamah	3,189	3,143	45.7	463.7	0.83
NE-2 Tekamah	2,869	1,975	894.4	456.6	0.00
NE-3[b] Mead	2,957	3,374	–417.3	390.1	0.04
OH-1 Mt. Sterling	2,392	2,052	340.4	588.8	0.22
OH-2 Bucyrus	2,736	2,561	175.41	566.3	0.50
OH-3[b] London	1,977	2,205	–227.9	371.8	0.20
WI-1 Hancock	2,617	1,707	910.6	1697.6	0.21
WI-2 Racine	2,754	2,516	237.3	769.3	0.44
WI-3[b] Hancock	3,631	4,051	–420.8	438.1	0.06
		1995			
IL-1 Champaign	2,587	2,724	–137.1	316.2	0.35
IL-2 Dwight	2,831	2,894	–63.9	602.6	0.83
IL-3[b] Newton	2,894	2,396	497.7	320.8	0.01
IN-1 Klondike	2,870	3,022	–152.9	683.6	0.62
IN-2 Romney	1,910	1,600	310.7	343.3	0.07
IN-3[b]Romney	2,829	3,122	–293.7	276.9	0.04
IA-1 Kanawha	2,254	2,558	–304.6	740.0	0.36
IA-2 Muscatine	2,141	1,840	301.2	340.3	0.08
IA-3 Ames	3,386	3,333	53.1	819.3	0.88
IA-4[b] Kanawha	2,958	3,578	–620.5	859.8	0.13
IA-5 Muscatine	2,130	1,818	312.2	296.9	0.04
IA-6[b] Ames	2,128	2,406	–278.1	452.0	0.18
KS-1 Rossville		1,844			
KS-2 Columbus	1,407	1,304	102.9	304.2	0.44
KS-3[b] Manhattan	3,472	3,969	–496.6	763.5	0.17
MI-1 St. Charles	1,884	1,524	359.5	452.2	0.10
MI-2 St. Charles	2,052	1,661	391.8	537.6	0.15
MI-3[b] Lansing	3,342	4,082	–739.9	825.2	0.07
MN-1 Sacred Heart	2,807	3,131	–324.0	500.3	0.15
MN-2 Lake Crystal	3,123	2,788	334.4	308.5	0.04
MN-3[b] Rosemont	3,624	3,695	–71.3	974.5	0.85
MO-1 Benton City	2,285	2,313	–28.8	254.0	0.80
MO-2 Edina	1,730	1,528	202.2	352.5	0.22
MO-3[b] Grand Pass	2,835	3,054	–218.8	248.7	0.08
NE-1 Tekamah	3,436	2,581	855.7	603.6	0.01
NE-2 Tekamah	2,708	2,052	655.5	483.1	0.01
NE-3[b] Mead	1,612	1,708	–96.3	420.0	0.61
OH-2 Jerry City	3,466	3,158	308.0	780.3	0.39
OH-3[b] West Milton	3,044	4,070	–1,026.3	2,038.8	0.28
OH-4 South Charleston	4,893	4,481	412.5	1,163.5	0.44
WI-1 Hancock	3,091	2,260	830.6	211.1	0.00
WI-2 Racine		2,909			
WI-3[b] Hancock	3,427	3,785	–358.4	854.7	0.21

[a] LSD used to compare MG has been averaged. The real LSD varies slightly due to unbalanced data.

[b] Low or noninfested site.

TABLE 4. Analysis of variance table used for analysis of data from 1994 and 1995 field studies.

Sources	1994 Degrees of freedom	1995 Degrees of freedom	Fixed (F) or random (R) effect
Infestation class	1	1	F
Productivity	2	2	F
Infestation class × productivity	2	2	F
Sites (infestation class × productivity)	24	27	R
Cultivar resistance	1	1	F
Cultivar resistance × infestation class	1	1	F
Cultivar resistance × productivity	2	2	F
Cultivar resistance × infestation class × productivity	2	2	F
Cultivar resistance × sites (infestation class × productivity)	24	27	F
Variety (cultivar resistance)	varied[a]	varied[a]	R
Infestation class (cultivar resistance)	varied[a]	varied[a]	R
Productivity (cultivar resistance)	varied[a]	varied[a]	R
Infestation class × productivity (cultivar resistance)	varied[a]	varied[a]	R

[a] Degrees of freedom varied with each maturity group zone (see Table 5).

will reproduce on Peking, PI 88788, and PI90763 (Golden et al., 1970; Riggs and Schmitt, 1988).

Mean yield across cultivars varied dramatically from site to site and year to year, and ranged from 1,407 kg/ha at Columbus, KS (infested), to 4,570 kg/ha at Crawfordsville, IA (noninfested), in 1994 and from 1,304 kg/ha at Columbus, KS (infested), to 4,893 kg/ha at South Charleston, OH (noninfested), in 1995 (Table 3). In general, yields across the region were higher in 1994 than in 1995.

Assessment of resistant vs. susceptible cultivar: Site productivity was a significant variable in the model. Productivity varied greatly from site to site and year to year. The site-by-year interaction was far more significant to the model than the presence or absence of SCN. The effect of SCN could be measured when the yield by site was treated as categorical date by productivity. Site productivity class (low, medium, or high productivity), site infestation class (SCN-infested or noninfested), and cultivar class (SCN-resistant or -susceptible) were not significant variables in the model (Table 5). In three of the four analyses, the interaction between cultivar class and site infestation class was significant at $p \leq 0.05$. The cultivar class by site infestation class interaction for the northern grouping of the full-season cultivars was significant at $P \leq 0.08$, indicating a trend in the data similar to that observed in the other three MG zone groupings. All interactions with productivity were not significant, indicating the relationship between resistance classification and SCN infestation is valid across productivity levels.

TABLE 5. Probability levels for source of variation for soybean yield in SCN-infested and noninfested fields in the north-central United States (1994 and 1995).

Source	Early[a]	Full-North	Full-South	Late[b]
Intercept	0.0001	0.0001	0.0001	0.0001
Infestation site class[a] (I)	0.80	0.52	0.81	0.81
Productivity[d] (P)	0.0001	0.0002	0.002	0.0001
I × P	0.44	0.47	0.92	0.75
Cultivar resistance class[e] (C)	0.42	0.37	0.45	0.49
C × I	0.005	0.079	0.049	0.006
C × P	0.61	0.84	0.49	0.75
C × I × P	0.85	0.74	0.21	0.12

[a] One MG earlier than maturity zone of the location; data excluded if more than one MG earlier than maturity zone (see Table 2).

[b] One MG later than maturity zone of the location; data excluded if more than one MG later than maturity zone (see Table 2).

[c] Infested or noninfested with SCN.

[d] Locations were separated into low (les than 1,600 kg/ha), moderate (1,600 to 2,400 kg/ha), or high (greater than 2,400 kg/ha).

[e] Cultivar either resistant or susceptible to SCN.

Table 6 demonstrated the yield penalty for planting these SCN-resistant cultivars in noninfested soil and for planting these susceptible cultivars in SCN-infested soil across the 63 sites in the north-central United States. The values presented in Table 6 are generalized least square means that were adjusted for the variables in the model. In all cases for the cultivars evaluated, there was a yield advantage to planting SCN-resistant cultivars at SCN-infested sites and a yield penalty for planting those cultivars in noninfested sites, compared to planting SCN-susceptible cultivars. The greatest yield advantage vs. loss of planting SCN-resistant cultivars was observed for full-season cultivars in MG zones I and II: +380 kg/ha on infested sites and −120 kg/ha on noninfested sites. Late-season cultivars demonstrated the least advantage of planting SCN-resistant cultivars on SCN-infested sites, with only a 100-kg/ha advantage over SCN-susceptible cultivars. Planting resistant cultivars at noninfested sites resulted in a 320-kg/ha disadvantage over susceptible cultivars. Yield advantage ranged from 50 kg/ha to 384 kg/ha. Yield disadvantage was inversely proportional, ranging from 120 to 320.

Effect of initial nematode population on yield: Initial SCN egg number was not a reliable predictor of yield loss. Tables 5 and 6 show the impact of SCN-infested sites on soybean yield and also the lesser impact of cultivar resistance on yield. Table 5 indicates the there was little relationship between site infestation class on yield of cultivars, regardless of their resistance class. Perhaps not surprisingly, no predictive yield loss equation could be developed for the north-central United States based

Table 6. Least square mean yield (kg/ha) of early, full, and late-season SCN-resistant and susceptible soybean cultivars across north-central U.S. locations and MG, 1994 and 1995 data combined.

	Early-season[a]		MG I & II		Late-season[b]		MG III & IV	
Cultivar reaction	SCN Infested	SCN Non-infested	SCN Infested	SCN Non-infested	SCN Infested	SCN Non-infested	SCN Infested	SCN Non-Infested
Resistant	2,480	2,230	2,230	2,110	2,120	1,940	2,300	2,100
Susceptible	2,200	2,350	1,850	2,230	2,020	2,260	2,250	2,360

[a] One MG earlier than maturity zone of the location; data excluded if more than one MG class earlier than maturity zone (see Table 2).
[b] One MG later than maturity zone of the location; data excluded if more than one MG class later than maturity zone (see Table 2).

on initial nematode egg number due to interactions with cultivar and environmental conditions at each site.

Discussion

Koenning (2004) reported a relationship between initial SCN egg number and soybean yield loss, but factors such as soil texture, soil moisture, and environment influenced the extent of loss. Niblack et al. (1992) found a linear relationship between initial SCN egg number and yield in a 2-yr microplot study using 'Corsoy79' (SCN-susceptible) and 'CN 290' (SCN-resistant) with artificial inoculations. Experimental parameters of initial nematode number or nematode inoculum and cultivar were constant, yet the slope of the predictive line was different for each year. In that study, the effect of increasing numbers of eggs and infective juveniles (J2) at planting on yield was described by a quadratic equation. Koenning and Barker (1995) reported similar results in their 2-yr study. Their predictive equations produced different slopes for each year, for irrigated vs. nonirrigated plots and for different soil textures. Our research was not consistent with the above studies and possible explanations for the difference could be due to the difference in geography and/or the extremes of environmental sites in this research that masked relationships when such variability was included.

Caution should be used in extrapolating a yield disadvantage of all SCN-resistant cultivars in non-SCN-infested soils compared to SCN-susceptible cultivars to SCN-resistant cultivars other than those used in this study. Recent efforts by soybean breeders have reduced the yield drag observed in the results of some of the earlier breeding efforts to incorporate SCN resistance (Tylka et al., 2002).

Consistent predictors between nematode population density and yield loss have remained elusive. Fallick et al. (2002) used the growth model CROPGRO-Soybean (Boote et al., 1998) to examine whether photosynthesis or root water uptake better explained the damage SCN caused to yield potential. They determined that photosynthesis measurements were better indicators of SCN damage than was root water uptake. More research is needed to determine which factors regulate the impact of the nematode on the plant. Understanding the mechanism of soybean grain yield loss mediated by SCN may help better define the relationship between soil levels of SCN and potential yield loss.

The strength of this research was in testing the relative importance of biotic and abiotic factors affecting the SCN-host plant interaction. Our findings indicate that generalizations cannot be made across fields or geographic areas and the best management strategy is to implement management strategies that will reduce SCN egg population density as soon as SCN is detected. These findings reinforce the importance of sampling new production fields or fields where the status of SCN infestation is not known for detection purposes and sampling infested fields to measure the efficacy of management strategies used in that field.

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