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Effect of Soybean Cyst Nematode (*Heterodera glycines*) on Yield of Resistant and Susceptible Soybean Cultivars Grown in Ohio[1]

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Abstract: Soybean (*Glycine max*) producers in Ohio rarely use soybean cyst nematode (*Heterodera glycines,* SCN)-resistant cultivars because of concerns over limited yield potential and lack of resistance to *Phytophthora sojae.* A two-year study was initiated to determine grain yield and nematode population increase on soybean cyst nematode-resistant cultivars in maturity groups II and III in production fields. Sites differed in soil texture, nematode densities, and *P. sojae* infestation at a number of locations in Ohio. Soil was assayed for nematode densities before planting and at harvest. Yields of resistant cultivars averaged 0% to 18% higher than those of susceptible cultivars in fine-textured soils with average preplant populations ranging from 463 to 14,330 SCN eggs/100 cm^3 soil. In coarse-textured soils, yields of susceptible cultivars were 21% to 56% less than the resistant cultivars with average preplant densities ranging from 1,661 to 15,558 SCN eggs/100 cm^3 soil. The reproductive index ranged from 0.1 to 5.5 for resistant cultivars and 0.4 to 112 for susceptible cultivars. In 1993, yield of *P. sojae*-susceptible, nematode-resistant 'Asgrow A 3431' was as high as yield of the *P. sojae*-resistant, nematode-susceptible cultivar 'Resnik' in a *Phytophthora*-infested field. The nematode-resistant cultivars Madison Experimental 131527 and Asgrow A3431 had higher yields than AgVenture AV1341 and susceptible cultivars Resnik and Kenwood when compared over five nematode-infested sites. Nematode-resistant cultivars were found to be excellent alternatives to currently grown susceptible cultivars for managing SCN where group III cultivars are used. However, better cultivar alternatives may be needed for sites with combined *Phytophthora* root rot and cyst nematode problems.

Key words: cultivar, *Heterodera glycines, nematode, Phytophthora sojae,* resistance, soybean, soybean cyst nematode.

Soybean cyst nematode, *Heterodera glycines* Ichinoche (SCN), has been a serious threat to soybean (*Glycine max* Merr.) yield in the southern United States for many years (Sciumbato, 1993; Wrather and Sciumbato, 1994). Although SCN was first discovered in the midwestern United States in Missouri in 1956 and Illinois in 1959 (Noel, 1992), it was not known to be common in other midwestern states until recently (Bird et al., 1989; Powers, 1987; Riedel and Golden, 1988; Sim and Todd, 1986). Currently, SCN is recognized as the most yield-limiting factor of soybean in the midwest (Doupnik, 1993).

Management of SCN has been practiced in the southern United States for many years. A rotation to nonhost crops for two years was sufficient to reduce SCN populations below threshold damage levels in the southern United States (Schmitt, 1991). Similar information on the use of crop rotation in more temperate climates is limited. Nematicides have been effective for control of SCN when combined with resistant cultivars (Noel, 1987), though economically difficult to justify (Smith et al., 1991). The most efficient and economic method of maintaining soybean yields in the presence of SCN is through the use of cultivars with resistance to *H. glycines.* Yield potential of resistant cultivars in maturity groups I-III has been tested for only a limited number of years (MacGuidwin et al., 1995; Noel and Sikora, 1990; Todd et al., 1995). Information is needed about how soybean cyst-resistant cultivars respond to other regional disease problems.

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Phytophthora sojae causes soybean seedling damping-off and root or stem rot in older plants. Plant losses and yield reductions of 100% can be seen in susceptible cultivars, though disease severity depends on cultivar susceptibility, rainfall, drainage, soil type, and tillage (Sinclair and Backman, 1989). Oospores can survive for years in the absence of a host, and, when soil is flooded, zoospores that are attracted to soybean roots can be formed (Sinclair and Backman, 1989). Management of diseases caused by *P. sojae* is based on an integrated approach relying on race-specific resistant or tolerant cultivars, metalaxyl seed treatments, and improved cultural conditions such as good soil drainage (Schmitthenner, 1985). *Phytophthora sojae* damage is associated with fine-textured soils (Schmitthenner, 1985) since fine-textured soils generally drain more slowly than coarse-textured soils. Damage due to soybean cyst nematode can be more severe in coarse-textured soils (Koenning et al., 1988). This has resulted in a belief that soybean cyst nematode and *P. sojae* would not be concurrent problems (A. F. Schmitthenner, pers. comm.). When soybean was infected with both pathogens, *P. sojae*-susceptible seedlings were more heavily damaged than when just *P. sojae* was present, but the presence of the nematode did not alter resistance to *P. sojae* (Adenifi et al., 1975).

The objectives of this project were to: i) evaluate soybean cyst nematode-resistant and -susceptible cultivars in maturity groups II and III in fields with a range of nematode densities and soil textures for yield and reproductive ability of soybean cyst nematode, ii) evaluate these same cultivars in the absence of soybean cyst nematode, and iii) evaluate these cultivars in fields known to have *P. sojae*. The goal was to obtain recommendations for the highest-yielding cultivars in the presence of soybean cyst nematode alone, and with *P. sojae*.

Materials and Methods

During 1993 and 1994, field sites were selected in 2 or 3 counties where SCN had been detected. Each year two uninfested sites were also included, of which one was a site with a history of damage from *P. sojae*. Infested sites in 1993 included two locations: a coarse-textured soil in Lucas County (Gilford fine sand, Rimer loamy sand, and Seward loamy fine sand [76% sand, 18% silt, 6% clay, 1.3% organic matter (OM)]) and fine-textured soil in Hardin County (Pewamo silty loam and Blount silt loam [8% sand, 52% silt, 40% clay, 2.2% OM]). Uninfested sites in 1993 were locations with fine-textured soil in Van Wert County (Pewamo silty clay loam [10% sand, 50% silt, 40% clay, 3.4% OM]) and *P. sojae*-infested soil at the Ohio Agricultural Research and Development Center (OARDC) in Hoyteville, Ohio (Hoytville clay [16% sand, 39% silt, 45% clay, 3.8% OM). Sites infested with SCN in 1994 included locations with coarse-textured soils in Henry County (Mermill loam [37% sand, 48% silt, 15% clay, 3.6% OM]) and Wood County (Ottokee and Spinks loamy fine sand [79% sand, 11% silt, 10% clay, 3.1% OM]), and fine-textured soil in Crawford County (Luray silty clay loam and Tiro silt loam [16% sand, 51% silt, 33% clay, 4.4% OM]). Uninfested locations included sites with fine-textured soils in Madison County (Westland silty clay loam [16% sand, 43% silt, 41% clay, 4.1% OM]) and the *P. sojae*-infested field at the OARDC in Hoytville, Ohio.

Plots were of two sizes in 1993, either 4.6 m wide by 24 m long and seeded with a drill (19-cm row width) or 3 m wide by 24 m long and seeded in four rows (76-cm row width). Standard soybean-growing practices for Ohio were used (Anonymous, 1989). Resistant cultivars tested were Asgrow A 3431, AgriPro AP3125, AgVenture AV1341, Country Mark FFR 291N and FFR 359N, DEKALB CX340C, Madison Experimental 131527, and Pioneer 9221 and 9312. Susceptible cultivars included Kenwood, Resnik, and Williams 82. All cultivars were in maturity group III except FFR291N, 9221, and Kenwood, which were in maturity group II.

Test sites in 1994 had plots four rows wide (76-cm spacing) and 6 m long. Resistant cultivars tested were A3431, AgriPro AP 3460, AV 1341, Callahan 3377, CX340C, FFR 359N, Exp. 131527, Golden Harvest H-1358, Good Buddy GB30C, ICI D368, Mycogene 340C, Nosco Classic NC 35E, Pioneer 9362, Stine 3432CN, and Voris 380. All resistant cultivars were in maturity group III. Susceptible cultivars were the same as in 1993. Tests were arranged in a randomized complete block design with four replications.

All plots were sampled for *H. glycines* at planting and harvest. Each sample was a composite of 10 soil cores (2.5-cm diam. × 20 cm deep) collected from the two center rows. The soil was mixed and a subsample was assayed for soybean cyst nematode second-stage juveniles (J2) with a modified Baermann method (Thistlethwayte, 1970), and for eggs by mechanically crushing cysts with a 40-ml Ten Broeck tissue grinder (Pyrex brand, Fisher Scientific, Pittsburgh, PA) and staining eggs with acid fuchsin (Hussey, 1985). A reproductive index was calculated for each plot by dividing the final population density (eggs) by the preplant population density (eggs + J2). A race determination (Riggs and Schmitt, 1988) was made on the populations from all but one (Lucas County) test locations from soil samples taken during a survey in 1992 and 1993 (Willson et al., 1996).

Stand counts were taken in each of the two center rows of a plot. The entire center two rows were harvested, and seed moisture and weight were determined. Yield per plot was calculated based on 13.5% seed moisture.

Data were analyzed using the general linear model procedures in SAS (SAS Institute, Cary, NC) with cultivar as the independent variable and yield and reproductive index as dependent variables for each site and year. The Waller-Duncan *k*-ratio *t*-test was used in analyses where the F-test was significant at $P < 0.05$. Six cultivars (A 3431, AV 1341, CX340C, Exp. 131527, Kenwood, and Resnik) were tested at all five infested sites, two uninfested sites, and a site with *P. sojae*. Data from SCN sites were combined, and analysis of variance was conducted with cultivar, site, and their interaction.

Results

In 1993, fields had zero to low densities of SCN (Van Wert and Hardin counties, respectively) or moderate (Lucas County) densities of soybean cyst nematode. At the Van Wert site, the susceptible cultivars yielded the same as the resistant cultivars (Table 1), indicating that no real differences

Table 1. Average soybean yield and reproduction of soybean cyst nematode (*Heterodera glycines*) on soybean cultivars in four fields in Ohio, 1993.

Cultivar	Maturity group	Resistance rating[b]	Yield (kg/ha) 1[c]	2	3	4	Relative reproduction[a] 1[c]	2
AgriPro 3125	III	R	3,485	2,779	3,630	2,302	0.9	1.6
AgVenture 1341	III	R	3,091	2,954	3,711	2,475	1.9	2.1
Asgrow 3431	III	R	3,875	2,471	3,609	2,797	3.9	2.2
Resnik	III	S	3,459	1,512	3,643	2,815	43.3	10.8
Williams 82	III	S	2,588	1,638	3,746	2,470	34.1	22.0
CountryMark FFR359N	III	R	—[e]	3,193	—	2,493	—	—
DEKALB CX340C	III	R	3,764	2,675	3,977	2,302	3.5	2.3
Madison Exp. 13527	III	R	3,735	3,091	3,480	2,326	5.5	2.8
Pioneer 9312	III	R	3,139	2,473	3,752	2,491	1.3	1.1
Kenwood	II	S	2,806	2,556	3,977	2,227	112.2	11.9
CountryMark FFR291N	II	R	3,026	2,875	3,732	2,056	1.6	2.9
Pioneer 9221	II	R	2,676	3,101	3,882	1,632	1.2	1.2
Minimum significant difference[d]			937	913	510	157	132.6	9.5

[a] Relative reproduction is the ratio of the harvest population density of *Heterodera glycines* to the preplant density.
[b] The resistance rating against *Heterodera glycines* race 3, where R is resistant and S is susceptible.
[c] Field location: 1 = Hardin County; 2 = Lucas County; 3 = Van Wert County; 4 = Hoyteville, Ohio.
[d] Mean separations based on the Waller-Duncan *k*-ratio *t*-test ($P = 0.05$).
[e] Dashes indicate that the cultivar was not planted at that location.

existed between these resistant and susceptible cultivars in uninfested or lightly infested soils. In Hardin County (fine-textured site), with an average preplant SCN density of 463 (SD = 499)/100 cm^3 soil, the susceptible cultivars yielded an average of 10% less than the resistant cultivars. The Lucas County field (coarse-textured soil) had an average preplant density of 1,951 SCN (SD = 1414)/100 cm^3 soil, and the susceptible cultivars yielded an average of 33% less than the resistant cultivars. At this site, all resistant cultivars had significantly higher average yields than Resnick.

On SCN-resistant cultivars, the average reproductive indices ranged from 0.9 to 5.5 at the Hardin County site and from 1.1 to 2.9 at the Lucas County site (Table 1). Reproduction indices on susceptible cultivars ranged from 34 to 112 at the Hardin County site and from 11 to 22 at the Lucas County site (Table 1).

Soybean cyst nematode preplant densities during 1994 were zero (Madison County), moderate (1,651 SCN [SD = 2,378]/100 cm^3 soil in Henry County), and high (14,320 SCN [SD = 6,385] for Crawford County and 15,557 SCN [9,558]/100 cm^3 soil for Wood County). Average yield in Madison County (no SCN present) did not differ between susceptible and resistant cultivars. Yield was significantly ($P = 0.05$) correlated with stand at this site, although average stand for each cultivar did not differ. However, stand problems may have led to lower yields than expected at this site (Table 2). In Crawford County (fine-textured soil), with a high preplant density of SCN race 14, the susceptible cultivars yielded 18% less than the resistant cultivars. All the susceptible cultivars yielded significantly less than NC 35E and Pioneer 9362 (Table 2). On a coarse-textured soil with moderate SCN preplant densities (Henry County), the susceptible cultivars Kenwood and Resnik had significantly lower yields than any resistant cultivars except for 3432CN (Table 2). On average, susceptible cultivars yielded 21% less than resistant cul-

TABLE 2. Average soybean yield and reproduction of soybean cyst nematode (*Heterodera glycines*) on soybean cultivars in five fields in Ohio, 1994.

Cultivar	Resistance rating[b]	Yield (kg/ha)					Relative reproduction[a]		
		Infested sites			Uninfested sites				
		5[d]	6	7	8	9	5	6	7
AgriPro 3460	R	3,562	4,231	2,680	2,445	2,857	0.3	0.6	0.4
AgVenture 1341	R	3,048	4,295	2,356	2,506	3,116	0.6	0.1	0.4
Asgrow 3431	R	3,756	4,241	3,037	2,468	3,375	0.2	0.2	0.3
Callahan 3377	R	3,124	4,561	2,612	2,396	3,029	0.2	0.5	0.5
Kenwood	S	2,258	3,180	1,170	1,913	—[e]	0.4	20.0	0.6
Resnik	S	3,124	3,732	1,182	2,547	3,247	1.4	16.5	2.2
Williams 82	S	3,071	2,915	—	2,957	—	—	—	
CountryMark FFR359N	R	3,374	4,498	2,489	2,464	2,977	0.2	0.7	0.4
DEKALB CX340C	R	3,439	4,210	2,603	2,799	3,202	0.1	0.3	1.1
Golden Harvest 1358	R	3,502	4,483	3,036	2,490	3,101	0.2	0.9	0.5
Good Buddy 30C	R	3,488	4,518	2,367	2,500	3,184	0.2	0.6	—
ICI D 368	R	2,809	4,473	2,901	2,158	3,260	0.2	0.7	0.4
Madison Exp. 131527	R	3,737	4,660	3,085	2,726	2,992	0.3	0.8	0.5
Mycogene 340C	R	3,049	4,311	2,249	2,507	3,155	0.1	0.3	1.1
Nosco Classic 35E	R	3,797	4,413	2,889	2,484	2,884	0.3	0.1	0.6
Pioneer 9362	R	3,965	4,553	2,772	2,781	3,265	0.2	0.4	0.4
Stine 3432CN	R	3,373	3,734	2,329	2,153	2,777	0.2	0.2	0.4
Voris 380	R	3,357	4,484	2,831	2,411	2,948	0.3	0.8	0.6
Minimum significant difference[c]			794	522	947	72	0.7	5.2	1.8

[a] Relative reproduction is the ratio of the harvest population density of *Heterodera glycines* to the preplant density.
[b] The resistance rating against *Heterodera glycines* race 3, where R is resistant and S is susceptible.
[c] Mean separations based on the Waller-Duncan *k*-ratio *t*-test ($P = 0.05$).
[d] Fields 5–9 are located in Crawford, Henry, Wood, and Madison counties, and near Hoyteville, Ohio.
[e] Dashes indicate that the cultivar was not planted in that location.

tivars at this location. Susceptible cultivars yielded 56% less than the resistant cultivars at the Wood County site (coarse-textured soil with high preplant density of SCN) (Table 2).

In 1994 the reproduction index was low in fields with high initial densities of SCN. At the Crawford County site, all index values were low and there were no differences between resistant and susceptible cultivars (Table 2). In Henry County, the reproductive index on susceptible cultivars was higher (17 to 20) than on resistant cultivars (0.1 to 0.9) (Table 2). At the Wood County site, indices for susceptible cultivars ranged from 0.6 to 2.2; for the resistant cultivars, reproductive indices ranged from 0.3 to 1.1 (Table 2).

A significant interaction occurred between cultivar and location when six cultivars were compared at five SCN-infested sites. The mean yield was significantly higher for Madison Experimental 131527 and Asgrow A3431 than for AgVenture AV 1341, Resnik, and Kenwood (Table 3). Yields were highest in Henry County, followed by Hardin, Crawford, Lucas and Wood counties. The interaction between cultivar and location was not significant when the data from Lucas County were omitted. Kenwood, a susceptible cultivar, yielded as much as most resistant cultivars at this site, though yields of this cultivar were lower than the resistant cultivars at all other SCN-infested sites. When these six cultivars were examined in two uninfested sites, no yield differences were seen between cultivars (data not shown).

The *Phytophthora*-resistant cultivar Resnik and the SCN-resistant cultivar Asgrow A3431 had the highest yields in 1993 in a field used for screening soybean lines against *P. sojae* (Table 1). Yields and stand (data not shown) were very poor in AgriPro 3125, DEKALB CX340C, Kenwood, Country Mark FFR 291N, and Pioneer 9221 (Table 1). Incidence of *P. sojae* in 1994 at the OARDC was low, and reaction of cultivars could not be critically evaluated.

Discussion

Yields of most resistant cultivars were equal to or better than susceptible cultivars at all SCN-infested sites. When a set of cultivars was examined across all sites in both years, the resistant cultivars averaged 19 to 39% higher yields than Resnik. In fields lightly or not infested with SCN, yields of all cultivars were similar. At Hardin County, where density of SCN was close to the economic threshold of 200 eggs/100 cm^3 soil (Francl, 1986; Niblack et al., 1992), differences between susceptible and resistant cultivars were small. At Lucas and Henry counties, similar moderate preplant densities of SCN were detected, yet yield losses were much more severe in Lucas County than in Henry County. Both sites had coarse-textured soil, but differences between sites included weather (less rain in 1993 at Lucas County than in 1994 at Henry County) and race of SCN (race 3 at Henry County and an unknown race at Lucas County). Yield losses were higher in a coarse-textured soil (Wood County) than a fine-textured soil (Crawford

TABLE 3. Effect of soybean cyst nematode (*Heterodera glycines*) on average yield for cultivars tested in both 1993 and 1994.

Cultivar	Maturity group	Resistance rating	Yield (kg/ha)	Yield as percentage[a] of Resnik
Madison Exp. 131527	III	R	3,793	139
Asgrow 3431	III	R	3,603	132
DEKALB CX340C	III	R	3,456	126
AgVenture 1341	III	R	3,260	119
Resnik	III	S	2,734	100
Kenwood	II	S	2,470	90
Minimum significant difference[a]			325	

[a] Minimum significant difference based on the Waller-Duncan *k*-ratio *t*-test with $P = 0.05$.

County) in sites with high preplant densities of SCN. Weather, preplant SCN densities, and soil texture were all important in determining damage potential to soybean. Whether SCN race was also a factor was difficult to determine because density-dependent reproduction was a stronger force in determining reproduction indices than race differences.

This study demonstrated that high preplant densities of SCN could be found in fine-textured soils as well as coarse-textured soils. Yield losses were higher in coarse-textured soils than fine-textured soils for preplant populations classified as high (>5,000 eggs/100 cm^3 soil). Yields of soybean grown in SCN-infested soils increased as the percentage of sand decreased (Koenning et al., 1988; Schmitt et al., 1987), which may be related to the reproduction of SCN in fine-textured soils (Young and Heatherly, 1990). Yield losses in this study were substantial in fine-textured soils, justifying the use of resistant cultivars on infested soil regardless of soil type. Nematode reproduction on resistant cultivars did occur (Hardin and Lucas counties), but was minimal in sites with either race 3 or 14.

Fine-textured soils are prone to drainage problems and vulnerable to *P. sojae* (Schmitthenner, 1985). In general, SCN-resistant cultivars used in 1993 had high root rot levels in a nursery used to screen soybean for tolerance to *P. sojae*. However, one cultivar (Asgrow 3431) yielded as well as the cultivar Resnik, developed with *P. sojae* tolerance as a major component. This result was based on only one season's data when pressure from *P. sojae* was high. Cultivars were tested in 1994 and 1995, but disease was minimal and cultivars could not be critically evaluated. It is important to further evaluate SCN-resistant cultivars on fine-textured soils that contain *P. sojae*. Soybean producers with fields infested with SCN and with low probability of *P. sojae* damage can choose among a variety of SCN-resistant cultivars. However, in soils that contain both organisms and have poor drainage (i.e. fine-textured soils), then increased risk of *P. sojae* must be weighed against SCN damage. Asgrow 3431 performed the best in fields infested with SCN or *P. sojae*.

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