Effect of *Heterodera glycines* on Yields of Nonnodulating Soybeans Grown at Various Nitrogen Levels[1]

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Abstract: Response of a nonnodulating soybean strain to infection by *Heterodera glycines* was greatly affected by applications of $NaNO_3$. Soybean yields from nematode infested microplots were reduced 71.8, 44.4, and 10.7% at low, medium, and high N levels, respectively, when compared with yields of noninfested plots at similar N levels. The results indicate that besides reducing root nodulation and N fixation, *H. glycines* causes soybean yield reductions by inciting deleterious host responses that increase with N deficiency.

The soybean cyst nematode (*Heterodera glycines Ichinohe*) reduces yields of soybean [*Glycine max* (L.) Merr.] by inhibiting root nodulation caused by *Rhizobium japonicum* (Kirch.) thereby inducing nitrogen (N) deficiency (3). Soybeans grown in cyst nematode infested soil with low available N manifest significant yield increases in response to applications of inorganic N (6) whereas well nodulated soybeans grown in noninfested soil show no such response (1). The fact that many nonleguminous crop plants are damaged by other species of *Heterodera* suggests that *H. glycines* may harmfully affect host processes other than nodulation and thereby contribute to yield reductions. This possibility was investigated during the summer of 1967 by using nodulating and nonnodulating isogenic soybean lines. Use of nonnodulating soybeans permits a measurement of host response to cyst nematode infections apart from the nematode's effect on reducing the supply of symbiotically fixed N.

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Materials and Methods

The experiment was conducted in glazed clay tiles (61 cm in diam) (8) containing a sandy loam, low in available N, and previously fumigated with methyl bromide and chloropicrin. Inoculum of *H. glycines,* originally from Castle Hayne, North Carolina, was increased in the greenhouse by growing soybeans for 3 months in 15 cm (6 inch) pots containing steamed soil infested with surface sterilized cysts. Nematode-infested plots each received 800 g of the resulting infested soil. In a bioassay of the inoculum, about 20 larvae emerged from cysts and egg masses recovered by flotation from 1 g of soil during a 9-day incubation at room temperature in Baermann funnels.

Plots were planted on June 9 with either nodulating or nonnodulating isogenic soybean lines, of var. Lee maturity, developed by E. E. Hartwig from the nonnodulating mutation due to a single recessive gene (11).

Plots planted with the nonnodulating line received four applications of $NaNO_3$ (16% N): before planting, and 18, 29, and 53 days after planting. At the respective fertilization dates, the low N level plots each received 0, 0, 2.5, and 2.5 g of $NaNO_3$. Medium N level plots received 2.5, 1.25, 5.0, and 5.0 g; and the high N level plots received 10.0, 5.0, 20.0, and 20.0 g. (One g/plot is equivalent to 33.7 kg/ha or 30 lb./acre.) Plots planted with the nodulating line received no N. Half the plots at each N level and half the plots planted with the nodulating line were infested with *H. glycines*; the other half of each group were not infested. All plots were fertilized before planting and 2 months after planting with 0-9-27 (13 g/plot per application). Treatments were replicated six times, and soybeans were harvested on October 26 and threshed by hand.

Soil samples were obtained from cyst nematode infested plots 90 days after planting. One-half pint (ca. 237 ml) of soil was assayed for larvae by the cyst-flotation, larval-emergence method (7). Populations were expressed as the number of larvae emerged from cysts incubated in Baermann funnels for 10 days.

Results and Discussion

By mid-July plants in nematode-infested plots receiving low and medium levels of N were not as green as plants in other treatments. Plants of the nodulating line growing in the absence of nematodes were darker green than plants in other treatments.

In nematode-infested plots, yields of the nonnodulating line increased with increasing N applications, and at each N level yields of nematode infested plots were lower than those of the noninfested controls (Table 1). Nematodes reduced yields of the nonnodulating line fertilized at the low, medium, and high N rate 71.8, 44.4 and 10.7%, respectively. Yields of the nodulating line were reduced 64.8% by nematodes. Greater yield differences between N levels were obtained in nematode-infested plots than in noninfested plots. In the latter, the nonnodulating line at the high N level yielded 85.5% of the nodulating line. These results are similar to those obtained in Iowa by Weber (10) who grew nodulating and nonnodulating isolines in fields fertilized with various rates of ammonium nitrate. In his study the available N had been partially immobilized by the addition of 18.1 metric tons of corncobs per ha (20 tons/acre). Graphical interpolation of his data to a N level similar to the highest level used in the present experiment showed that his nonnodulating line yielded about 81.9% of his nodulating line. The close agreement of these results with those of the present experiment indicates that the response of the nonnodulating line to N fertilization in the present experiment would probably be similar under field conditions.

TABLE 1. Effect of *Heterodera glycines* on yields of nodulating (Nod) and nonnodulating (Nonnod) lines of soybeans at various nitrogen fertilizer levels.

		Nematode infested		Noninfested control
Soybean line	Nitrogen level[a]	Nematode populations	Yield	Yield
			g	g
Nonnod	low	2640[b]	18.1 A[c]	64.2 B
Nonnod	medium	2670	34.2 A	61.6 B
Nonnod	high	730	120.4 C	134.9 C
Nod	none	2670	55.8 B	158.3 D

[a] Low = 5.0 g $NaNO_3$/plot; medium = 13.75 g $NaNO_3$/plot; high = 55 g $NaNO_3$/plot. Data are means of six replications.

[b] Number of larvae emerged from cysts recovered from 220 ml of soil.

[c] Treatments followed by the same letter do not differ at the 5% level of significance according to Duncan's multiple range test.

Since initial nematode populations were low, the nodulating line in infested soil probably nodulated early in the season and fixed some N since its yield was comparable to that of the noninfected nonnodulating control at the low N level and was significantly above the yield of the nonnodulating line in infested soil at the low and medium N levels. With the exception of the low nematode populations in the high N plots, there was little difference in average nematode populations among the various treatments (Table 1).

These results and those previously mentioned (3, 6) indicate that, overall, the yield reduction sustained by soybean infected by *H. glycines* is the result of: a) N deficiency caused by reduced nodulation; and b) other deleterious host responses to nematode activities, probably similar to those caused by other species of *Heterodera.* As cyst nematode infected soybeans become increasingly deficient in N, pathological responses of the host increase resulting in drastic yield reductions. This is indicated by the inverse relationship between yield reduction of the nematode infected nonnodulating line and the rate of N fertilization. In North Carolina near-complete soybean crop failures have been observed in cyst nematode infested soils with low available N. N-deficient plants sustaining high cyst nematode populations also may be predisposed to other diseases which could play a role in reducing soybean yields (9).

Experiments dealing with N fertilization of crops affected by other species of *Heterodera* unfortunately have not included fumigated control plots (2, 5). Investigations, similar to the one herein described, with other physiological strains of *H. glycines* or with other species of *Heterodera* may help describe basic similarities or differences in the pathological responses of plants to these nematodes.

Instances where relatively high soybean cyst nematode populations do not result in large yield losses in susceptible varieties may be explained by the presence of either sufficient available N to prevent excessive deleterious host reactions or a strain of *H. glycines* that does not completely inhibit nodulation.

The relatively low nematode population in high N level plots disagrees with previous results where nematode populations rose as application of ammonium nitrate increased (6). Unlike the present experiment, the previous trial was conducted in a nonfumigated field and presence of other soil-inhabiting pathogens probably played a complementary role in substantially reducing root growth in low N field plots thereby reducing nematode populations. Death and extremely poor growth of plants in the field plots receiving no N was probably caused by *Fusarium* wilt (9). Also, the source of applied N (nitrate or ammonia) may influence the nematode's life cycle or larval emergence in the assays (4).

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