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Relationship Between Time of Infection with *Heterodera glycines* and Soybean Yield[1]

J. A. Wrather and S. C. Anand[2]

Abstract: Experiments were conducted to determine the relationship between time of infection by *Heterodera glycines* and soybean growth in the greenhouse and yield of plants grown in the field. Soybean cultivar Essex seedlings growing in the greenhouse were inoculated with *H. glycines* at 2, 4, or 6 weeks after planting. Seedling growth was inhibited by *H. glycines* infection at 2 or 4 weeks after planting but not at 6 weeks. Infection of Essex by *H. glycines* in the field was delayed 2–6 weeks by nematicides. Yields were significantly increased when *H. glycines* infection was delayed 2 weeks by nematicide treatment. Essex yields were highest when infection was delayed 6 weeks, equalling the yield of the *H. glycines*-resistant cultivar Asgrow 5474. The effect of *H. glycines* on soybean growth in the greenhouse and yields in the field declined when infection was delayed 6 weeks. Thus, soybean sensitivity to *H. glycines* seemed to diminish with age of the soybean plants.

Key words: Glycine max, Heterodera glycines, nematicide, soybean, soybean cyst nematode.

Soybean cyst nematode (SCN) *Heterodera glycines* Ichinohe, the most prominent cyst nematode in the United States, is a serious pest of soybean (*Glycine max* (L.) Merr.) in the central and southeast areas of the country and is of increasing significance in the north-central area (11). Yield losses due to SCN in 16 southern states were estimated to be 5.77% in 1985 (7). SCN-resistant cultivars, crop rotation, and nematicides can be used to reduce losses due to this nematode.

Yield losses may be minimized if soybeans are kept free of *H. glycines* early in the season, for example, by nematicide application (5,10), but the relationship between time of infection by *H. glycines* and soybean damage is unknown. Brodie (4) found that tobacco yields were reduced by *Meloidogyne javanica* if infection occurred during the first month after transplanting. He found that tobacco seedlings transplanted into nematicide-treated soil infested with *M. javanica* were less galled during the first month than seedlings growing in nontreated soil. At 2 months after transplanting, roots were equally galled in both treated and untreated plots, yet all of the nematicide treatments improved yields. The objective of our study was to determine the relationship between the time of infection with *H. glycines* and soybean growth in the greenhouse and yield of field-grown plants.

Materials and Methods

A Typic Udipsamments soil with 85% sand, 12% silt, 3% clay, and pH of 6.3 was obtained from a field near Portageville, Missouri. The soil was steam pasteurized and placed in 10-cm-d pots. Two seeds of the soybean cultivar Essex, susceptible to all races of *H. glycines,* were planted in each pot. The soil in each pot was infested with eggs of *H. glycines* (25 eggs/cm^3 soil) when the plants were 2, 4, or 6 weeks old. Each treatment was replicated seven times in a randomized complete block design. The plants were maintained in a greenhouse at 25–30 C. Plants were harvested 10 weeks after the test was initiated, and data were collected. The shoots and washed roots were dried in an oven at 50 C for 3 days and weighed. Before oven drying, the fresh root volume was calculated by water displacement. The experiment was repeated, and the data were pooled for analysis of variance.

Field experiments were conducted in 1985 and 1986 to determine if age affected

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[2] Associate Professor of Plant Pathology and Professor of Agronomy, University of Missouri, Delta Center, Portageville, MO 63873.

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TABLE 1. Growth of soybeans when inoculated at different ages with *Heterodera glycines* eggs.

Age when inoculated	Weight (g)†		Root volume (ml)
	Shoot	Root	
Noninoculated	12.6	20.6	21.2
2 weeks	4.9	5.9	9.4
4 weeks	6.3	7.6	6.8
6 weeks	11.2	16.4	16.8
LSD 0.05	3.6	5.9	6.1

Values are means of 14 replications.
† Shoot (leaves, petioles, stems) and roots were harvested from 10-week-old plants, oven dried, and weighed.

the sensitivity of field-grown soybeans to infection by *H. glycines*. In 1985 and 1986 field plots were established near Portageville on a Typic Argiudolls soil consisting of 70% sand, 25% silt, and 5% clay with a pH of 6.0. The land was planted to cotton in 1983 and Essex soybean in 1984. Trifluralin was incorporated preplant at 0.38 liters/ha to control early season weeds, particularly grasses. Basalin at 0.19 liters/ha was used to control broadleaf weeds after soybeans emerged.

Four nematicide treatments were applied to delay soybean infection by *H. glycines*. Treatments one and two were aldicarb or carbofuran at 21.6 g a.i./100 m of row applied at planting in a 20-cm-wide T-band. Granules were applied to the row as the furrow was closed so they were mixed with the soil filling the furrow and covering the row. The third treatment was aldicarb applied in the same manner at planting and followed 3 weeks later by a second application at the same rate applied in a 20-cm-wide band over the row. Ethylene dibromide (EDB) at 361.5 g a.i./100 m of row, the fourth treatment, was injected 20 cm deep 24 hours before planting, half applied through each of two chisels per row 12 cm apart.

Soybean cultivars Essex, and Asgrow 5474, resistant to races 3 and 4, were planted in late May. Asgrow 5474 was planted only in untreated soil. Each plot was four rows wide (95-cm row spacing) and 6.1 m long.

Soil samples for cyst extraction consisting of six soil cores (each 2.5 cm d × 20 cm deep) from the central 1-m² area of each plot were taken just before nematicide treatment. Cysts were extracted from a 227-g wet weight subsample by a semi-automatic elutriator with an extraction efficiency of ca. 75%. The numbers of preplant cysts per 227 g field soil were 140 in 1985 and 128 in 1986.

The extent nematicides delayed soybean infection by *H. glycines* was estimated by measuring nematicide activity in the soil at intervals after application. A bioassay was used to assess nematicide activity. At 2, 4, and 6 weeks after planting, six soil cores were collected from within the two rows in the central 1-m² area of each plot. Each core was obtained by forcing a plastic pipe (2.5 cm d × 20 cm long) into the soil and extracting the pipe with the soil core intact. One 5-day-old Essex seedling was transplanted into the soil within each pipe and maintained in a growth chamber at 26

TABLE 2. *Heterodera glycines* juveniles per gram of root of soybeans transplanted into soil collected 2, 4, and 6 weeks after nematicide treatment.†

Treatment	Rate (g a.i./100 m row)	2	4	6	LSD 0.05
Nontreated		157.0	144.0	140.8	59.1
Aldicarb	21.6	3.4	40.1	53.7	19.1
Aldicarb (2×)‡	21.6	13.3	4.6	19.6	5.4
Carbofuran	21.6	64.9	126.5	119.5	47.0
EDB	361.5	69.9	158.9	160.4	48.7
LSD 0.05		34.8	35.9	35.3	

Values are means of 10 replications combined over 2 years.
† Seven-day-old seedlings were transplanted into soil, and the roots were harvested 10 days later for juvenile analysis.
‡ Plots treated with aldicarb twice—at planting and 3 weeks later.

TABLE 3. Yield of field-grown soybeans on plots treated with nematicides.

Variety	Treatment	Rate (g a.i./ 100 m row)	Yield (kg/ha)		
			1985	1986	Average
Essex	Nontreated		1,552	2,757	2,151
Essex	Aldicarb	21.6	2,185	3,350	2,770
Essex	Aldicarb (2×)†	21.6	2,105	3,357	2,760
Essex	Carbofuran	21.6	1,852	3,012	2,430
Essex	EDB	361.5	1,998	3,297	2,650
Asgrow 5474			2,218	3,423	2,817
LSD 0.05			138	171	105

Values are means of five replications each year.
† Plots were treated with aldicarb twice—at planting and 3 weeks later.

C. Fourteen days later the roots were extracted from each pipe, washed, blot dried, weighed, and chopped in a blender with 50 ml tap water for 30 seconds. One milliliter of stock staining solution (0.35 g acid fuchsin, 25.0 ml acetic acid, and 75 ml tap water) was added to the homogenate which was boiled for 1 minute then allowed to cool. Third-stage (J3) and fourth-stage (J4) swollen *H. glycines* juveniles in the homogenate were counted. At maturity the grain yield in each central 1-m^2 area was recorded. Each treatment was replicated four times in a randomized complete block design, and the data from each year and combined years were subjected to analysis of variance.

RESULTS

Shoot weight, root weight, and root volume of greenhouse-grown Essex seedlings inoculated with *H. glycines* at 2 or 4 weeks after planting were significantly less (61 and 50% for shoot weight, 71 and 64% for root weight) than those of the noninoculated control (Table 1). Shoot weight, root weight, and root volume of plants inoculated 6 weeks after planting were not reduced by nematode infection.

Essex soybeans growing in soil collected 2 weeks after treatment with carbofuran, EDB, or aldicarb had significantly fewer *H. glycines* juveniles per gram of root than the control plants (Table 2). Soybeans growing in soil collected 4 weeks after treatment with carbofuran or EDB had the same number of juveniles per gram of root as the control plants. Soybeans growing in soil collected 4 and 6 weeks after treatment with either aldicarb treatment had significantly fewer juveniles per gram of root than any other treatment. There appeared to be some differences in juveniles per gram of root among the aldicarb treatments, but the difference was not significant.

All nematicide treatments in 1985 and 1986 significantly increased yields (Table 3). Similar increases resulted from each nematicide treatment each year even though yields were significantly different between years. Yields from aldicarb-treated plots were significantly greater than the other nematicide treatments in combined years and were similar to the yield of the resistant Asgrow 5474.

DISCUSSION

Yields of field-grown Essex were significantly greater when *H. glycines* infection was delayed 2 weeks by nematicides. When infection was delayed 6 weeks, Essex yields were greatest and equalled those of the SCN resistant cultivar Asgrow 5474.

The effect of *H. glycines* on soybean growth in the greenhouse and yields in the field declined when infection was delayed 6 weeks after planting. Thus, sensitivity of soybean to damage by *H. glycines* diminished as the plants aged. Similar relationships have been demonstrated between tobacco and *M. javanica* (4), tomato and *M. incognita* (2), and sugar beet and *H. schachtii* (8). Soybean seems to be most sensitive to *H. glycines* damage during the first 6 weeks

after emergence. This may explain the correlation between initial populations of *H. glycines* in the soil and soybean growth and yield (1,3,6,9).

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