Impact of Population Density of *Heterodera glycines* on Soybean Canopy Growth and Weed Competition

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ABSTRACT

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Soybean (*Glycine max*) canopy size and subsequent growth of annual weeds were influenced by initial population density (Pi) of the soybean cyst nematode (SCN), *Heterodera glycines*, in eastern North Carolina field studies. Soybean biomass accumulation and canopy size were inversely related to increasing Pi of SCN, resulting in open canopy soybeans at moderate and high Pi levels. More photosynthetically active solar radiation reached the soil surface in high-SCN, open-canopy soybeans than in low-SCN treatments. Weed biomass was 63–92% greater in soybeans with the highest SCN Pi levels and open canopies.

Production of soybean (*Glycine max* (L.) Merrill) in North Carolina is negatively influenced by a pest complex, which includes the soybean cyst nematode (SCN), *Heterodera glycines* Ichinohe, and annual weed species. Although yield loss has been attributed to each pest (5,10), it is important to determine interactive effects among this complex of pests on soybean and their effects on each other. To improve our understanding of the soybean crop-pest ecology, quantification of the impact of these multiple stress factors on soybean growth is required.

The fundamental relationship between numbers of plant-parasitic nematodes and growth and yield of annual crops is best expressed as a function of preplant nematode population densities (Pi) on a logarithmic scale (4). Soybean canopy development is inversely related to the Pi of SCN (2). Preliminary observations suggested that SCN indirectly increased the incidence and severity of late-season weed problems through the mechanism of reduced soybean canopy size. Open soybean canopies provide large areas of exposed soil where weed seeds may germinate and become established (7,9) as a result of optimum light, moisture, and nutrient conditions (11). Early-season weed control can be implemented by the use of preplant and preemergence herbicides combined with timely cultivation. Late-season control, however, can be maintained most efficiently by adequate shading from the soybean canopy (9,11).

Other studies have addressed the influence of SCN Pi and weed density on the establishment and survival of the defoliating insect, *Helicoverpa zea* Boddie, in soybean canopies, the impact of *H. zea* defoliation on late-season SCN population densities, and the effects of this multiple pest complex on soybean yield (1–3). The objective of this study was to determine the influence of SCN Pi on soybean and weed growth response.

MATERIALS AND METHODS

Experimental designs. Field experiments were conducted from 1985 to 1988 in eastern North Carolina. Study sites were located at Elizabeth City, Pasquotank County, in 1985; Tarboro, Edgecombe County, in 1986; Como, Hertford County, in 1986 and 1987; and Wenona, Washington County, in 1988.

Soil texture was sandy loam (62–69% sand, 24–32% silt, and 6–7% clay) at Elizabeth City and Como, loamy sand (77% sand, 18% silt, and 5% clay) at Tarboro, and organic sand (89% sand, 7% silt, and 4% clay) at Wenona.

In the year preceding each study, corn was grown at Elizabeth City, Tarboro, and Como, followed by a winter wheat cover crop at Elizabeth City. At Wenona, various crop rotation sequences were used in 1986 and 1987 to manipulate SCN Pi in plots. These crop rotations were corn and sorghum, soybean and corn, and continuous soybean in 1986 and 1987, respectively. There were no nematicides used in any of the test sites. The SCN populations were race 2 at Como and Wenona and race 5 at Elizabeth City and Tarboro.

Before planting at Elizabeth City, Tarboro, and Como, 40 plots (3.0–4.1 m wide [four rows] × 4.6 m long) were selected from 400 to give a range of SCN Pi based on counts determined by assay of 500 cm^3 of soil. Samples were processed by a combination of elutriation (6) and centrifugation (8). SCN Pi ranges were categorized into zero, low (300–900 SCN eggs per 500 cm^3 of soil), moderate (2,800–6,000 SCN eggs per 500 cm^3 of soil), and high (8,800–20,000 SCN eggs per 500 cm^3 of soil) based on relative nematode abundance at each site. Experiments were set up in a completely randomized design with 10 replications for each of the four SCN Pi levels. Tests were planted 27 May to 4 June with the SCN-susceptible cultivar Coker 156.

At Wenona, SCN Pi ranges (eggs per 500 cm^3 of soil) for the 1988 test included low = 175, moderate = 1,150, and high = 4,400. Treatments were arranged in a randomized complete block design with four replications. Plot size was eight rows (0.9-m spacing) by 15.2 m long, and soybeans were planted 24 May with the SCN-susceptible cultivar Deltapine 105.

Sampling procedures. To evaluate the influence of SCN Pi on soybean plant growth, soybean biomass accumulation and canopy size were measured in field studies. Soybean plant height, width of plant canopy per row, and distance between canopies of adjacent rows were measured at approximately weekly intervals during August at Tarboro in 1986, Como in 1986 and 1987, and Wenona in 1988. Canopy size measurements were taken at two randomly selected locations in each plot with a meter stick. Additional soybean biomass measurements consisting of leaflet, stem, and pod dry weights of five randomly selected plants per plot were collected at Wenona at 5- to 10-day intervals from 13 July to 23 August 1988.

Photosynthetically active radiation (PAR) measurements were made at Wenona in 1988 with a quantum sensor (model 170, Li-Cor Inc., Lincoln, NE). PAR measurements were taken at the top of the soybean canopy and at the soil surface under the canopy to monitor canopy development from 18 July through 25 August. Three readings were taken at the soil surface 0.15, 0.30, and 0.45 m from the row center in two randomly selected locations in each plot between 11 a.m. and 1:30 p.m. on relatively cloud-free days. Soil surface read-

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ings were averaged and expressed as a percentage of readings that were taken at the top of the soybean canopy. By subtracting this percentage from 100, PAR intercepted by the soybean foliage was obtained.

Weed biomass measurements were collected at Elizabeth City on 11 September 1985, at Tarboro on 8 October 1986, and at Como on 12 October 1987. Weed growth was so minimal at Como in 1986 and Wenona in 1988 that biomass was not evaluated. Fresh weed weights in plots were determined in a randomly selected square-meter area.

Statistical analyses. Standard statistical analyses were done with the general linear models procedure of the Statistical Analysis System (13). Mean separations were determined by orthogonal contrasts. Linear regressions were fitted to soybean plant growth parameters, and differences in slopes over time were tested with repeated measures analysis (12).

RESULTS

Soybean growth response. The influence of SCN Pi on soybean plant growth over time was described by differences in shoot (leaflet, stem, and pod) dry weights at Wenona (Fig. 1). Shoot dry weights for low, moderate, and high SCN Pi levels fitted linear models ($r^2 =$ 0.95–0.98, $P = 0.001$). Differences in shoot weights among SCN Pi levels on individual sampling dates were greatest from 4 to 23 August ($P =$ 0.05–0.009). Slopes for low and moderate SCN Pi treatments (1.61 and 1.50, respectively) were greater ($P = 0.05$) than the slope for high SCN Pi (1.05).

Soybean canopy size was influenced ($P \leq 0.05$) by SCN Pi at all locations (Table 1). Although soybean canopy measurements were collected throughout August, data from representative dates in mid-August demonstrate the influence of SCN Pi on canopy size. Soybean plant height and width of canopy per row generally decreased with increasing SCN Pi. The mean distance between canopies of adjacent rows was greater in high SCN Pi plots at Como in 1987 and at Wenona in 1988 only. Plants with high SCN Pi levels were generally severely stunted and chlorotic.

More photosynthetically active radiation (PAR) was intercepted by the soybean canopy in low than in moderate and high SCN Pi treatments ($P = 0.02$ and 0.05 on 8 and 25 July, respectively) at Wenona (Fig. 2). The maximum percentage of total PAR intercepted by all soybean canopies occurred on 8 August and was 72, 67, and 59% in low, moderate, and high SCN Pi plots, respectively. Drought conditions prevented soybean canopies from closing more fully. The wilting of plants in the field resulted in a decrease in percent PAR intercepted by all plants from 8 to 25 August, before occurrence of any normal plant senescence.

Weed biomass accumulation. Weed growth was positively influenced by increasing SCN Pi (Fig. 3). The dominant annual weed species were large crabgrass (*Digitaria sanguinalis* (L.) Scop.), broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash), fall panicum (*Panicum dichotomiflorum* Michx.), common lamb's-quarter (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), common ragweed (*Ambrosia artemisiifolia* L.), and morning-glory (*Ipomoea* spp.). At Elizabeth City in 1985, the major ground cover plant species was volunteer wheat (*Triticum aestivum* L.). Fresh weed biomass (g/m^2) was greatest ($P =$ 0.0001–0.05) in highest SCN Pi treatments.

DISCUSSION

Soybean canopy size and biomass accumulation were inversely related to increasing initial population density of SCN, resulting in soybeans with smaller and more open canopies at moderate and

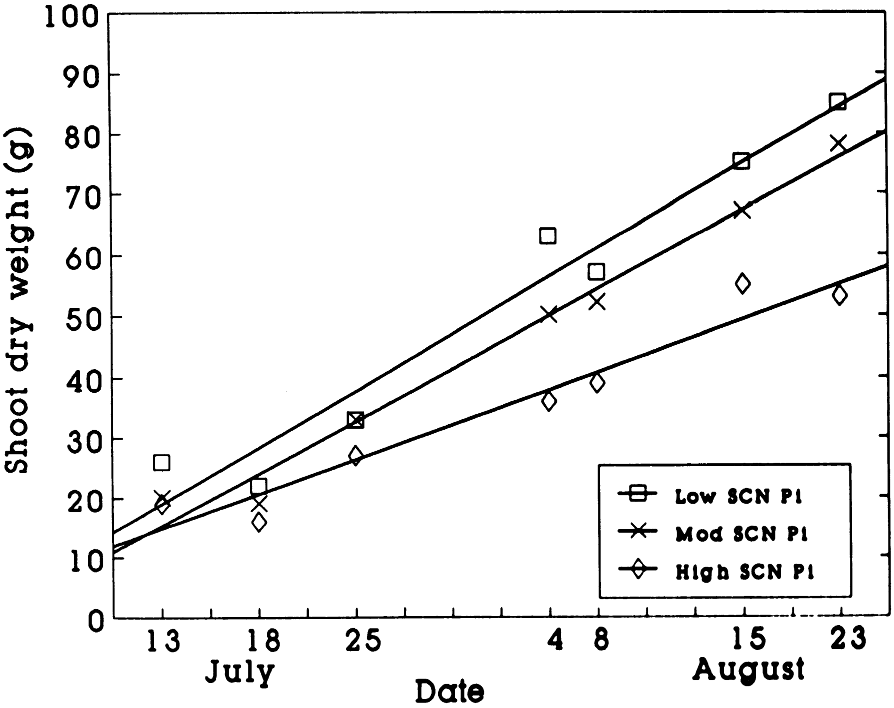

Fig. 1. The influence of soybean cyst nematode (SCN) initial population density (Pi) on soybean shoot dry weight (g) at Wenona, 1988. Average SCN Pi levels: low = 175, moderate = 1,150, and high = 4,400 eggs per 500 cm^3 of soil. Regression equations: low SCN Pi, $y = 1.61x - 292$, $r^2 = 0.95$; moderate SCN Pi, $y = 1.50x - 275$, $r^2 = 0.98$; and high SCN Pi, $y = 1.05x - 189$, $r^2 = 0.95$ where y = shoot dry weight (g) and x = sampling date.

Table 1. Influence of *Heterodera glycines* initial population density (Pi) on soybean canopy size from representative dates, 12–20 August

Year and location	*H. glycines* Pi	$\bar{x}$ Plant height		$\bar{x}$ Canopy width		$\bar{x}$ Distance[a]	
		Cm	SE	Cm	SE	Cm	SE
1986 Tarboro	Zero	51.3	2.2	39.2	2.6	37.4	3.4
	Low	45.9	1.9	34.3	2.6	38.1	3.1
	Moderate	43.6	2.0	30.6	2.2	41.2	3.4
	High	44.9	2.3	30.2	3.1	41.3	3.8
	P> *F*	0.06		0.02		0.66	
1986 Como	Zero	98.2	3.0	67.6	2.0	22.1	4.0
	Low	87.9	2.0	66.5	1.5	20.7	1.7
	Moderate	81.6	4.1	65.2	3.7	21.0	4.4
	High	75.6	3.6	60.5	2.2	29.0	2.9
	P> *F*	0.0002		0.22		0.30	
1987 Como	Zero	61.2	2.3	47.8	2.0	44.7	2.0
	Low	56.1	2.4	43.4	2.1	51.6	2.1
	Moderate	54.4	1.7	42.9	1.9	50.8	2.4
	High	53.6	2.4	39.6	2.3	53.6	2.3
	P> *F*	0.05		0.02		0.02	
1988 Wenona	Low	101.0	3.3	57.4	3.0	38.9	3.0
	Moderate	89.0	6.4	49.1	3.6	50.1	3.8
	High	89.4	3.8	48.5	2.0	51.3	1.7
	P> *F*	0.04		0.05		0.01	

[a] Mean distance between canopies of adjacent rows.

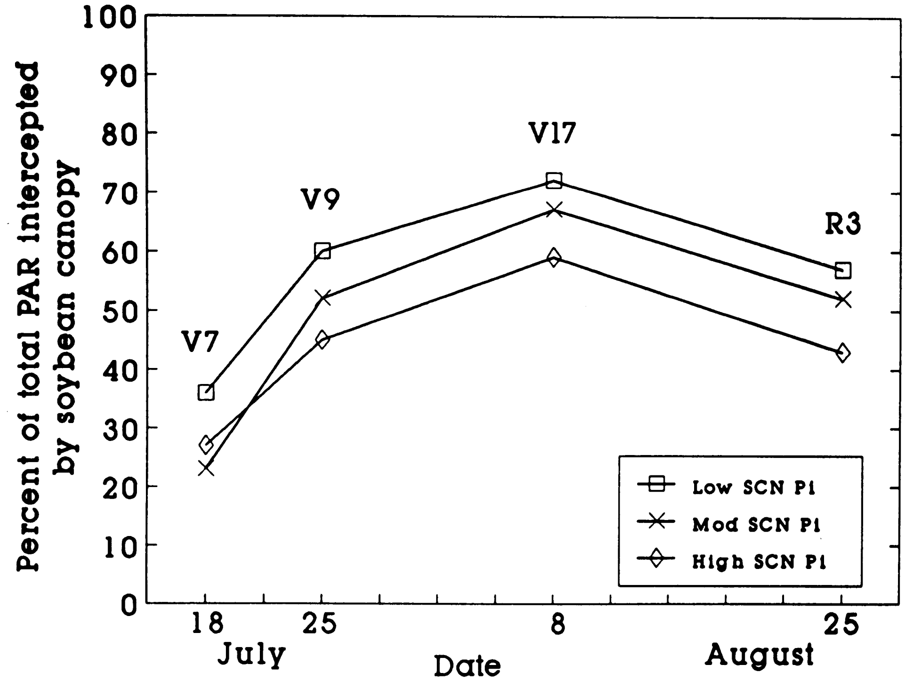

Fig. 2. Percentage of total photosynthetically active radiation (PAR) intercepted by the soybean canopy as influenced by the soybean cyst nematode (SCN) initial population density (Pi) at Wenona, 1988. The predominant soybean growth stage present at each sampling date is indicated above the data point.

high SCN Pi levels (2,800–20,000 SCN eggs per 500 cm^3 of soil). Weed biomass was increased by 63, 77, and 92% in these soybeans with high SCN Pi (>8,800 eggs per 500 cm^3 of soil) and more open canopies compared with plots without the nematode.

Soybean growth during low moisture and high temperature conditions is especially sensitive to further stresses attributable to SCN damage (14). This was indicated by the increased divergence of soybean biomass at Wenona among SCN Pi levels during 4–23 August, a period of hot (daily maximum temperatures 28-38 C), dry conditions at Wenona (3).

Damage to soybeans by moderate to high SCN Pi reduces crop competitiveness, thus, weeds can obtain the solar radiation, water, and nutrients otherwise used primarily by the vigorously growing soybeans (9,11). Early pod development and pod filling occurs during mid- to late August when the competition from weeds is especially detrimental to soybean (7,11). Additional stresses from defoliating insects and flower and pod feeders, such as *H. zea*, also occurs during August (2). Thus, it is critical that plant canopies are closed as early as possible to alleviate late-season pest and environmental stresses.

Weeds present during mid- and late season become established in soybean rows within a few weeks of planting (11). The resurgence of weed populations following suppression at planting would be more likely to occur in small-sized, open soybean canopies where plants are stunted by SCN.

An important approach to the management of the pest complex considered in this study is the use of predictive capabilities for expected nematode damage to the crop. Soil samples taken in the fall to determine SCN population densities can be used to predict crop performance the following season (14). Implementation of nematode management tactics that result in closed soybean canopies would reduce the likelihood of late-season weed and other pest (e.g., insect) problems.

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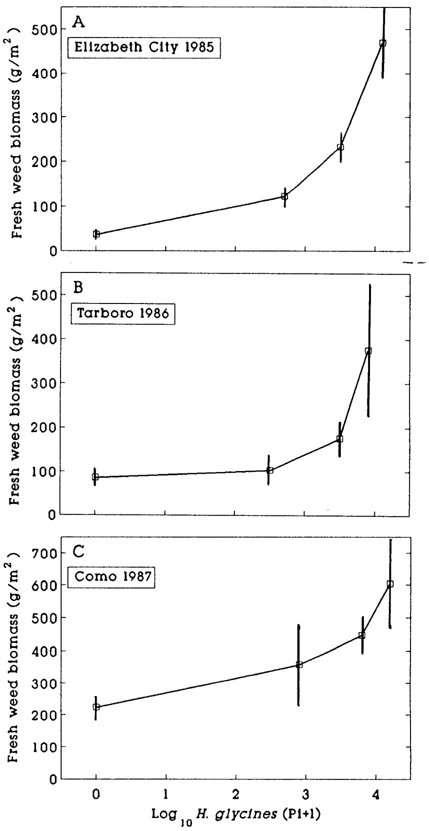

Fig. 3. The effect of *Heterodera glycines* initial population density (Pi) on fresh weed biomass (g/m^2 ± SE). **(A)** Elizabeth City, 11 September 1985; **(B)** Tarboro, 8 October 1986; and **(C)** Como, 12 October 1987.

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