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# Chemical Control of *Hoplolaimus columbus* on Cotton and Soybean[1]

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*Abstract:* Seven experiments, three on soybean and four on cotton, were conducted in *Hoplolaimus columbus*-infested soil in southern North Carolina to determine the benefits of chemical soil treatment. Locations were selected to give a range of initial population (Pi) densities. Soil fumigation with 1,3-D and soil treatment with a combination of aldicarb plus fenamiphos (1.1 kg a.i./ha) each provided good control of this nematode. Yield responses considered to be significant were achieved only on the high Pi site.
*Key words:* chemical control, Columbia lance nematode, cotton, *Glycine max*, *Gossypium hirsutum*, *Hoplolaimus columbus*, nematicide, soybean, 1,3-dichloropropene (1,3-D).

Cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* (L.) Merr.), economically important crops in the southeastern United States, are damaged by several species of plant-parasitic nematodes. *Hoplolaimus columbus* Sher causes substantial yield losses to both crops in southern North Carolina and the coastal regions of South Carolina and Georgia.

Management options for *H. columbus* are limited. Corn, the most common rotational crop with cotton and soybean, is a good host (J. P. Noe, pers. comm.); thus, rotation is of little use for reducing population densities of *H. columbus.* Some tolerance has been identified in soybean germplasm (3,10), but neither tolerance nor resistance has been observed in cotton (8). Economic analysis of chemical control of *H. columbus* is needed to determine whether nematicide usage is a reasonable option for soybean and cotton growers.

The pattern of nematicide use to control *H. columbus* has been dynamic because of changes in the availability of effective, low cost products. Management of this nematode was achieved with DBCP (1,4,5), which is no longer available. Other fumigants require a waiting period before the crop can be planted. Nonfumigants have been less consistent than fumigants at controlling *H. columbus* and are relatively expensive.

Since *H. columbus* is a relatively new pest in North Carolina (first confirmed in 1974), there is a need to establish a basis for implementing chemical management. Routine chemical treatments are not wise economically or environmentally. Therefore, the objective of this research was to determine the most effective nematicide or combinations of nematicides for managing the nematode and enhancing yields.

## Materials and Methods

Seven randomized complete block design experiments, four with cotton and three with soybeans, were conducted in fields infested with *H. columbus.* Five tests (two soybean and three cotton) were in Scotland County, and two (one soybean and one cotton) were in Robeson County, North Carolina. The soil textures at these sites were very similar: 89–92% sand, 7–9% silt, and 1–2% clay.

Six experiments in 1987 had eight treatments arranged in a randomized complete block design with four replications. The seventh experiment, conducted in 1989, had seven treatments with six replications. For cotton, the fumigant 1,3-dichloropropene (1,3-D) was applied at 28 liters/ha (2.56 ml/m of row) to a depth of 36-cm with a commercial subsoiler through a gravity-flow meter on 23 April (preplant) and 29 April 1987 (at plant), and at 28 liters/ha and 56 liters/ha (5.12 ml/m of

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row) on 19 April 1989 (preplant). For soybean, the fumigant was applied at 19 liters/ha (1.43 ml/m of row) and 28 liters/ha on 11 May 1987. Chisel slits were sealed with a 15-cm-high bed. Nonfumigants were applied 29 April 1987 and 28 April 1989 on cotton and 1 June 1987 on soybean. Aldicarb at 1.7 kg a.i./ha (0.14 g a.i./m of row) and fenamiphos at 2.2 kg/ha (0.20 g a.i./m of row) were applied in an 18-cm-wide band between the seed furrow opener and press wheel. Aldicarb and fenamiphos were applied together in two combinations, one in-furrow and the other in an 18-cm-wide band, each at 1.1 kg a.i./ha (0.1 g a.i./m of row). All nematicide-treated plots were subsoiled to a depth of 35 cm. An untreated control was subsoiled, and in 1987 a second control which was not subsoiled was included in each experiment. In 1987 the granular nematicides were delivered through glass jars mounted on a commercial planter; openings in the jar lids allowed the desired flow rates when the planter was moving at a ground speed of 1.34 m/second. These granular materials were applied with Gandy applicators in 1989.

Cotton 'Coker 315' was planted on 29 April 1987 and 'KC380' on 28 April 1989. Soybean 'Coker 317' was planted at the two Scotland County sites (Rushin, Gibson) and 'Coker 156' at the Robeson County (Walton) site on 1 June 1987 in rows spaced 102 cm apart. Plots were four rows wide and 12.2 m long.

All data were taken from the center two rows of each plot. Ten to twelve 2.5-cm-d soil cores were taken 20-cm deep in the row and composited on 23 April 1987 and 19 April 1989 from cotton tests and on 11 May from soybean tests for determination of initial population densities. Midseason samples were collected on 27 August 1987 and 16 August 1989 from both crops. Nematodes were extracted from 500 $cm^3$ soil by a combination of elutriation (2) and centrifugation (6) and from roots collected on a 70-$\mu$m-pore sieve after placing them in a mist chamber for 5 days. Cotton was harvested with a commercial harvester from the entire length of the two center rows from the Rushin site in 1987. It was harvested by hand for the remaining sites. A systematically selected 1.82 m of each center row at the Walton site was harvested on 21 September 1989. At the Gibson site, cotton was picked from 1.82 m of one row on 21 September and 13 October 1987 and on 3 October 1989. The center two rows of soybean were harvested on 5 November 1987 with an Almaco PMC10 combine (Allen Machine Co., Nevada, IA).

Seed bed preparation utilized conventional tillage and bedding. The herbicide fluometuron (2.24 kg a.i./ha) was applied broadcast on cotton plots immediately after planting. A tank mix of the herbicides alachlor (2.24 kg a.i./ha) and imazaquin (1.12 kg a.i./ha) was applied broadcast to the soybean sites immediately after planting. In addition, paraquat (0.56 kg a.i./ha) was added to the mixture at the Rushin and Gibson sites to kill emerging weeds. All plots were cultivated periodically for control of weeds. Cotton was defoliated by the growers with a commercial defoliant. Rainfall was the only source of water. Data were subjected to an analysis of variance for a randomized complete block design. Treatment comparisons were made using orthogonal contrasts.

## Results

*Cotton:* The most consistent control of *H. columbus* was achieved with 1,3-D (Fig. 1). The time of fumigant application did not produce consistent results. Midseason nematode population densities were 2.1 times higher with the at-plant treatment of 1,3-D than with the preplant treatment in the field with the lowest Pi (Fig. 1A), but they were 1.8 times higher in the preplant vs. the at-plant plots with medium-range Pi (Fig. 1B). These fumigant treatments were equivalent at the highest Pi site (Fig. 1C). Aldicarb plus fenamiphos also provided good control of *H. columbus* in fields with medium to high Pi (Fig. 1B–D). Aldicarb and fenamiphos applied alone generally gave poor control.

Nematicide treatments enhanced lint

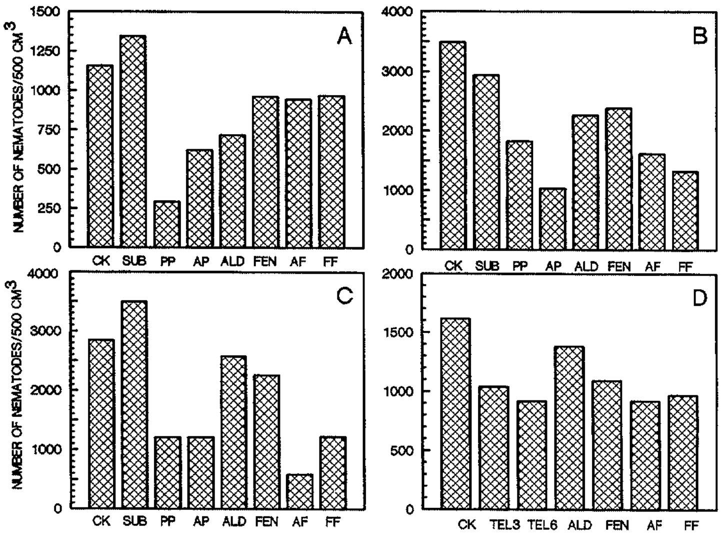


FIG. 1. Numbers of *Hoplolaimus columbus*/500 cm³ at midseason in soil and cotton roots from plots treated with nematicide, 1987 and 1989. A) Rushin site with Pi = 391. B) Walton site with Pi = 664. C) Gibson site with Pi = 991. D) Gibson site with Pi = 667. CK = untreated and not subsoiled. SUB = untreated and subsoiled. PP = 1,3-D applied preplant. AP = 1,3-D applied at plant. TEL3 = 1,3-D applied preplant at 28 liters/ha. TEL6 = 1,3-D applied preplant at 56 liters/ha. ALD = aldicarb. FEN = fenamiphos. AF = aldicarb in-furrow and fenamiphos applied in an 18-cm-wide band. FF = fenamiphos applied in-furrow and aldicarb applied in an 18-cm-wide band. Orthogonal contrasts were performed to designate differences among treatments. Comparisons: controls vs. treated—$P = 0.01$ for all sites; fumigants vs. nonfumigants—Rushin ($P = 0.01$), Walton ($P = 0.04$); PP vs. AP—Walton ($P = 0.02$); combination treatment of aldicarb and fenamiphos vs. each chemical alone—Walton ($P = 0.04$), Gibson ($P = 0.01$); AF vs. FF—Gibson ($P = 0.05$).

yield in fields with moderate to high Pi, but this effect was greater ($P < 0.05$) than the control in 1989 (Table 1). Subsoiling without chemical treatments increased yields over the nonsubsoiled control at the Gibson site in 1987. At this site, application of 1,3-D before planting gave a greater yield ($P < 0.10$) than the at-plant 1,3-D

TABLE 1. Yield of cotton lint in response to nematicide treatment of *Hoplolaimus columbus*-infested soil in four experiments.

| | Dosage | | | Yield (kg/ha)§ | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Gibson | |
| Treatment† | Per m of row | Per ha | Application method‡ | Rushin | Walton | 1987 | 1989 |
| 1,3-D | 2.56 ml | 28.0 liters | IPP | 275 | 1,062 | 621 | 1,272 |
| 1,3-D | 5.12 ml | 56.0 liters | IPP | | | | 1,175 |
| 1,3-D | 2.56 ml | 28.0 liters | IAP | 281 | 1,050 | 438 | |
| Aldicarb (A) | 0.14 g a.i. | 1.7 kg | BND | 254 | 949 | 478 | 1,235 |
| Fenamiphos (F) | 0.20 g a.i. | 2.2 kg | BND | 269 | 871 | 539 | 1,167 |
| A + F | 0.1 + 0.1 g a.i. | 1.1 + 1.1 kg | SF + BND | 276 | 1,150 | 601 | 1,099 |
| F + A | 0.1 + 0.1 g a.i. | 1.1 + 1.1 kg | SF + BND | 251 | 937 | 755 | 1,162 |
| Control-subsoiled | | | | 301 | 1,037 | 438 | 887 |
| Control | | | | 276 | 961 | 382 | |
| Contrasts | | | | | c, d | a, b, c, d | E |

Letters designate differences in yield as determined by orthogonal contrasts. Capital letters indicate significance at $P < 0.05$, lower case $0.05 \leq P < 0.10$: A = subsoiled control vs. nonsubsoiled control; B = 1,3-D preplant vs. 1,3-D at plant; C = aldicarb in-furrow and fenamiphos band vs. fenamiphos in-furrow + aldicarb band; D = combination of aldicarb and fenamiphos vs. those chemicals alone; E = untreated control vs. nematicide treatments.

† All plots treated with nematicides were in-row subsoiled to a depth of 36 cm.

‡ IPP = injected 35 cm deep 6 days before planting; IAP = injected 35 cm deep at planting; BND = placed in 18-cm-wide band directly in front of the planter press wheel; SF = applied to seed furrow.

§ Initial population density/500 cm³ soil: Rushin = 391, Walton = 664, Gibson (1987) = 991, and Gibson (1989) = 667.

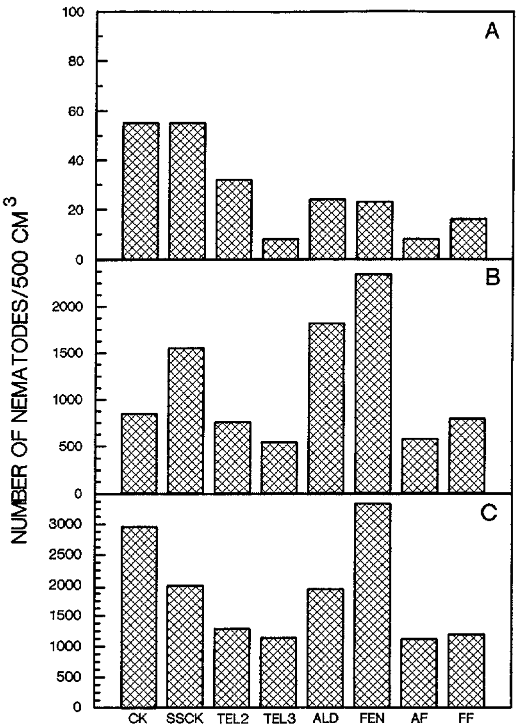


FIG. 2. Population density of *Hoplolaimus columbus*/500 $cm^3$ soil and soybean roots from plots at midseason. A) Rushin site with Pi = 11. B) Walton site with Pi = 216. C) Gibson site with Pi = 743. CK = untreated control and not subsoiled. SSCK = untreated and subsoiled. TEL2 = 1,3-D applied preplant at 19 liters/ha, TEL3 = 1,3-D applied preplant at 28 liters/ha. ALD = aldicarb. FEN = fenamiphos. AF = aldicarb in-furrow and fenamiphos applied in an 18-cm-wide band. FF = fenamiphos applied in-furrow and aldicarb applied in an 18-cm-wide band. Comparisons for orthogonal contrasts to designate differences among treatments: untreated control vs. treatments—Rushin ($P = 0.01$), Gibson ($P = 0.07$); TEL2 vs. TEL3—Rushin ($P = 0.10$); combination of aldicarb and fenamiphos vs. each chemical alone—Walton and Gibson ($P = 0.01$); ALD vs. FEN—Gibson ($P = 0.08$).

treatment in 1987. The combination of aldicarb plus fenamiphos treatments enhanced lint yield ($P < 0.10$) more than these chemicals applied alone at the Walton and Gibson sites in 1987. The combination of aldicarb in-furrow and fenamiphos applied in a band was superior to the opposite combination at the Walton site, but the converse response occurred at the Gibson site in 1987.

*Soybean:* Fumigant treatments and those treatments involving a combination of aldicarb and fenamiphos gave good control of *H. columbus* in these tests (Fig. 2). Population densities at the Rushin site remained low in all plots (Fig. 2A). The fumigants and combination treatments gave the best nematode control and these four treatments were similar at the Walton site (Fig. 2B). The higher fumigant rate tended to be more effective than the lower rate (Fig. 2). Numbers of *H. columbus* were kept low by aldicarb and fenamiphos combination treatments in locations with medium and high Pi, whereas the population density increased to high levels where aldicarb or fenamiphos was applied alone (Fig. 2B, C).

Application of fumigants resulted in higher yields than nonfumigants only at the highest Pi location (Gibson farm) (Table 2). Subsoiling was beneficial ($P < 0.05$) at the Gibson site, but it adversely affected yield at the Walton location ($P < 0.10$). A large numerical increase in yield due to subsoiling at the Rushin farm was not statistically significant. Fenamiphos in-furrow plus aldicarb in a band gave 1.5 and 1.1 times more grain at the Rushin and Walton farms than treatment with aldicarb in-furrow plus fenamiphos in a band.

## DISCUSSION

Significant control of *H. columbus* with nematicides and subsequent increase in plant yield are typically achieved in fields with high population densities. In a previous soybean study in North Carolina, most nematicides gave significant control and a net profit from the use of nematicides (12). Aldicarb at rates of 0.56, 1.12, and 1.68 kg a.i./ha suppressed population development of *H. columbus* in South Carolina (9). The low rate is recommended in that state, although the researchers indicate that economics are marginal (9).

Management decisions for *H. columbus* should be based on economical returns. Soil texture must also be considered, since soybean can tolerate damage from highly pathogenic nematodes such as *Heterodera glycines* Ichinohe in fine-textured soils (13). Soybean and cotton plants probably can

TABLE 2. Soybean yields in response to nematicide treatment of *Hoplolaimus columbus*-infested soil in three experiments, 1987.

| Treatment† | Dosage | | Application method‡ | Yield (kg/ha)§ | | |
|---|---|---|---|---|---|---|
| | Per m of row | Per ha | | Rushin | Walton | Gibson |
| 1,3-D | 1.74 ml | 19.0 liters | I | 1,396 | 3,104 | 2,362 |
| 1,3-D | 2.56 ml | 28.0 liters | I | 1,337 | 3,049 | 2,293 |
| Aldicarb (A) | 0.14 g a.i. | 1.7 kg | BND | 1,089 | 2,929 | 1,886 |
| Fenamiphos (F) | 0.20 g a.i. | 2.2 kg | BND | 1,190 | 2,820 | 1,446 |
| A + F | 0.1 + 0.1 g a.i. | 1.1 + 1.1 kg | SF + BND | 892 | 2,788 | 1,794 |
| F + A | 0.1 + 0.1 g a.i. | 1.1 + 1.1 kg | SF + BND | 1,369 | 3,108 | 1,790 |
| Control-subsoiled | | | | 1,424 | 2,682 | 2,032 |
| Control | | | | 970 | 3,016 | 1,442 |
| Contrasts | | | | c | a, c | A, B |

Letters designate difference in yield as determined by orthogonal contrasts. Capital letters indicate significance at $P < 0.05$, lower case $0.05 \leq P < 0.10$: A = subsoiled untreated control vs. nonsubsoiled untreated control; B = fumigants vs. nonfumigants; C = aldicarb in-furrow + fenamiphos applied in a 18-cm-wide band vs. the opposite application of these materials.

† All nematicide-treated plots were subsoiled.

‡ I = injected 35 cm deep; BND = placed in 18-cm-wide band directly in front of the planter press wheel; SF = in seed furrow.

§ Initial population density/500 $cm^3$ soil: Rushin = 11, Walton = 216, Gibson = 743.

withstand some damage from *H. columbus* before yields are affected. Although the best nematicides do not reduce nematode populations to zero or nondetectable levels, highly effective nematicides can be good tools that enable a researcher to gain insight into population levels that may have an economic impact. Based on this study, as well as previous ones (8,9,12), low to moderate numbers may not generally cause sufficient damage to justify treatment with a nematicide. A population density of one or two *H. columbus*/$cm^3$ soil is tentatively selected as a treatment threshold for advisory purposes.

Achieving high and profitable yields of soybean or cotton in soils infested with *H. columbus* will require more than simply applying an effective nematicide. Important cultural practices include crop rotation, growing tolerant cultivars (3,7–10,12), planting crops at times that help avoid damage by the nematode (10), and subsoiling (1,4,5,11). Subsoiling was beneficial at the Gibson farm and showed similar trends in three of four of the other sites. Subsoiling and bedding enhance cotton yield in fields over those plants growing in bedded soil without subsoiling (1,4). Chemical soil treatment had little affect on yield over subsoiling in two Georgia studies (1,4), but in a third test, yield enhancement occurred in the second year only in fumigated plots (11).

Subsoiling is a recommended practice in North Carolina soils with a "hard pan" that restricts root penetration to the subsoil. *Hoplolaimus columbus* is predominantly in the top 18 cm of soil and this distribution is influenced little by subsoiling (5). Since the top 18 cm of soil is the most biologically active zone in the soil profile, subsoiling may provide some protection to crops because roots can grow into a zone that has fewer *H. columbus* and more water and nutrients.

Management of *H. columbus* is complicated by the shortage of nonhost crops commonly grown in rotation with cotton and soybean. Furthermore, cotton is grown in monoculture in many fields infested with *H. columbus.* A reasonable approach to management would be to assay to determine Pi and then use a combination of practices to minimize damage. Subsoiling, growing a tolerant cultivar, plus application of 1,3-D or a combination of aldicarb plus fenamiphos should enable most growers to profitably produce cotton and soybean.

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