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# Effect of Soil pH on Nematicide Efficacy on Soybean[1]

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*Abstract:* To determine the efficacy of selected nematicides under different soil pH regimes in a sandy soil, soil pH ranges were achieved by adding lime or sulfur. Nematicides increased soybean yields, and their efficacy was generally not influenced by soil pH. *Belonolaimus longicaudatus* was negatively correlated ($r = -0.58$, $P = 0.01$) with yield in 1977.
*Key words:* *Belonolaimus longicaudatus,* chemical control, *Criconemella ornata,* DBCP, ethoprop, fenamiphos, fensulfothion, *Glycine max, Heterodera glycines,* ring nematode, soybean, soybean cyst nematode, sting nematode.

Low soil pH and nematodes are common problems in the sandy coastal plain soils of the southeastern United States. A pH level of 5.8–6.2 gives conditions for optimum growth and yield of soybean, *Glycine max* (L.) Merr., whereas yields are suppressed as soils become more acidic than pH 5.8 (10). Liming of acid soils results in neutralization of exchangeable aluminum, a better supply of calcium for nodule initiation, and increased availability of molybdenum (3,11).

Correlations of nematode numbers with soil pH vary (8). On vetch, for example, *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans–Stekhoven remains at or above the maintenance level from pH 5.1 through 6.5, but it thrives best at pH 5.5–5.8 (7). Above pH 6.6 population densities decline. Hatching of *Meloidogyne javanica* (Treub) Chitwood is inhibited below pH 5.0 when tested in a range of pH 4.0–8.0 (12). *Xiphinema americanum* Cobb is negatively correlated and *Helicotylenchus pseudorobustus* (Steiner) Golden is positively correlated with soil pH in Iowa soybean fields (9). More plant-parasitic nematodes occur on soybean at pH 6.0 than at either pH 4.0 or pH 8.0 (1).

Efficacy of oxamyl and carbofuran is affected by soil pH in the greenhouse (6). Oxamyl and carbofuran at 0.5 mg a.i./kg soil are more effective at pH 7.5 than at pH 5.5 and 6.5. Toxicity to nematodes of both nematicides at 2 and 8 mg a.i./kg soil is not affected by soil pH. In contrast, fenamiphos at rates of 0.5, 2.0, and 8.0 mg a.i./kg of soil is equally effective in controlling nematodes at pH 5.5, 6.5, and 7.5.

The objective of this research was to determine the efficacy of certain nematicides under selected soil-acidity regimes under field conditions.

## Materials and Methods

A Lakeland soil (typic quartzipsamments—soil texture was 93% sand, 3% silt, 4% clay, 0.8% organic matter; pH 5.0) in the coastal plains of North Carolina was selected for this study. The soil texture throughout the profile was sand. Two experiments were conducted in different areas of the same field in 1976 and 1977. Soil pH was adjusted with calcium carbonate (1976), calcium hydroxide (1977), or sulfur (1977). These materials were broadcast by hand on the appropriate plots and incorporated into the upper 15 cm of soil with a rototiller. The pH of the soil was determined (1) each time samples were collected for nematode assay.

Cultural practices consisted of conventional tillage for plant bed preparation, broadcast application of trifluralin (0.22 kg a.i./ha), and mechanical cultivation for weed control. Rainfall was the only source of water.

*Experiment 1:* The experimental design was a split plot latin square with four replications. Whole plots were four rows wide

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TABLE 1. Soybean yield as affected by soil pH and fensulfothion in a sandy soil in 1976.

| Lime added (kg/ha equivalent) | Yield (g/12 m) | | | pH | |
|---|---|---|---|---|---|
| | Fensulfothion† | | | | |
| | + | − | Mean | Plant | Harvest |
| 0 | 1,900 ax | 1,157 ax | 1,529 | 5.3 | 5.7 |
| 1,152 | 1,941 ax | 1,644 ax | 1,793 | 5.3 | 6.3 |
| 2,304 | 1,993 ax | 1,529 ax | 1,761 | 5.4 | 6.5 |
| 3,456 | 1,522 ax | 1,129 ax | 1,326 | 5.3 | 6.6 |
| Mean | 1,839** | 1,365 | | | |

Means within columns or across columns are not different ($P = 0.05$).

** Indicates significance at $P = 0.01$ between nematicide and no nematicide treatments averaged over lime treatments.

† + = fensulfothion applied 2.24 kg a.i./ha (0.22 g/m row); − = no fensulfothion added.

TABLE 2. Soybean yield at three levels of soil pH in soil treated with four nematicides in a deep sandy soil in 1977.

| Nematicide | Yield (g/18 m) | | |
|---|---|---|---|
| | pH 5.5 | pH 6.0 | pH 6.7 |
| Fenamiphos | 2,603 ax | 2,086 ax | 2,890 ax |
| Fensulfothion | 1,695 aby | 1,839 axy | 2,674 ax |
| Ethoprop | 1,718 abx | 1,539 ax | 1,945 bx |
| DBCP | 998 bx | 1,827 ax | 1,545 bx |
| Untreated | 1,075 bxy | 460 by | 1,381 bx |

Means within columns (a, b) or across columns (x, y) followed by the same letter are not significantly different ($P = 0.05$).

(97-cm row spacing) by 12 m long. Plots were treated with the equivalent of either 0, 1,152, 2,304, or 3,456 kg/ha of finely ground calcium carbonate (commercial agricultural limestone). Subplots (four rows × 6 m) were treated with fensulfothion at 0 or 2.24 kg a.i./ha (0.22 g/m row). The nematicide was applied on the soil surface in a 30-cm-wide band with a Gandy applicator (Gandy Company, Owatonna, MN) 18 days before planting and incorporated into the upper 15 cm of soil with a rototiller. All plots were planted with 'Essex' soybean and fertilized with 95 kg/ha 4-12-24 (N-P-K) on 25 May 1976. Eight to ten 2.5-cm-d soil cores were taken 15–20 cm deep in the two middle rows of each subplot and composited for nematode assay 18 days before planting and 20 and 98 days after planting. The nematodes were extracted from 100 $cm^3$ soil by sieving and centrifugal flotation (4) and counted. Soybeans were harvested from the two middle rows of each subplot on 19 October 1976.

*Experiment 2:* Soil pH levels, adjusted by incorporating 56.7 kg sulfur or 22.7 kg calcium hydroxide into the soil of each plot, were 5.5, 6.0, and 6.7 at planting time. Whole plots were divided into five subplots each consisting of four 9-m-long rows spaced 97 cm apart. Subplots were treated with either 1,2-dibromo-3-chloropropane (DBCP) at 10 kg a.i./ha (0.97 g/m row), fensulfothion at 4.5 kg a.i./ha (0.43 g/m row), fenamiphos at 4.5 kg a.i./ha (0.43 g/m row), or ethoprop at 4.5 kg a.i./ha (0.43 g/m row). DBCP was injected with a chisel 23 cm deep, and then a 30-cm-high soil bed was formed with a commercial disc bedder. The granular nematicides were applied with a commercial gravity flow applicator in a 30-cm-wide band and incorporated with a Ferguson tilrovator (Ferguson Manufacturing Co., Suffolk, VA) to a depth of 15 cm. All plots were planted to Essex (26 seeds/m row). The experimental design was a split plot with four replications.

Soil samples were taken the day before planting, 35 and 74 days after planting, and at harvest for pH determination and nematode assay. Ten soil probes (2.5 cm d × 20 cm deep) were collected in the row from the two middle rows of each subplot and composited. Nematodes were extracted from 500 $cm^3$ soil by elutriation (2) and centrifugal flotation (4). Seeds were harvested 25 October 1977 from the two middle rows of each subplot.

## RESULTS AND DISCUSSION

*Experiment 1:* Mean soybean seed yields averaged over lime treatments were greater ($P = 0.01$) in fensulfothion-treated plots than in the control plots (Table 1). Yields between pH treatments did not differ ($P = 0.05$).

Population densities of *Criconemella ornata* (Raski) Luc & Raski at 98 days after planting in plots not treated with fensulfothion were near 100/500 $cm^3$ soil,

TABLE 3. *Belonolaimus longicaudatus* at 35 and 74 days after planting in a deep sandy soil as influenced by nematicides and soil pH in 1977.

| | *B. longicaudatus* (no./500 cm³ soil) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 35 days | | | | 74 days | | | |
| | pH 5.5 | pH 6.0 | pH 6.7 | Mean | pH 5.5 | pH 6.0 | pH 6.7 | Mean |
| Fenamiphos | 15 | 35 | 15 | 22* | 3 | 23 | 8 | 11* |
| Fensulfothion | 23 | 18 | 28 | 23* | 3 | 15 | 5 | 8* |
| Ethoprop | 8 | 93 | 80 | 60 | 38 | 10 | 50 | 33 |
| DBCP | 38 | 70 | 20 | 43 | 58 | 20 | 18 | 32 |
| Untreated | 23 | 80 | 60 | 54 | 53 | 55 | 33 | 47 |
| Mean | 21 | 59 | 41 | | 31 | 25 | 23 | |

* Indicates significance at $P = 0.05$ for mean nematode numbers among nematicide treatments.

whereas they were 280/500 cm³ soil in treated plots. Numbers of *Heterodera glycines* and *Belonolaimus longicaudatus* did not differ ($P = 0.05$) among treatments.

*Experiment 2:* All nematicides increased yields ($P = 0.05$) at pH 6.0, whereas only fenamiphos increased yield at pH 5.5 (Table 2). Fenamiphos and fensulfothion increased yields at pH 6.7 (Table 2). Fensulfothion-treated soybeans yielded 37% more ($P = 0.05$) at pH 6.7 than at pH 5.5 (Table 2). In the untreated plots, yields were 67% higher ($P = 0.05$) at pH 6.7 than at pH 6.0. Yields did not differ ($P = 0.05$) among pH treatments for fenamiphos, ethoprop, and DBCP.

*Belonolaimus longicaudatus* population densities at 35 and 74 days after planting were negatively correlated ($r = -0.58$, $P = 0.01$) with yield. The greatest numbers were recovered from soil at pH 6.0 35 days after planting (Table 3). Fenamiphos and fensulfothion provided the most consistent reduction in numbers of this nematode.

Nematicides increased soybean yields in both experiments and were not generally affected by soil pH. The small number of replications (four) and the interplot variation (1976 subplot CV = 19%, whole plot CV = 92%) may account for the low number of treatment means with significant differences. Miller (6) also found that soil pH had little effect on the activity of fenamiphos.

Soil pH is important, although probably indirectly, for nematode activity (1,7–9,12). Greatest numbers of *B. longicaudatus* and generally lowest yields at pH 6.0 are indications that the host–parasite relationship is favored more at this pH than at either more acid or alkaline soils. Thus, the benefits of liming to achieve pH 6.0, the optimum for soybean growth in the coastal plain of North Carolina, are offset by this nematode.

Several factors may possibly be involved in the higher yields at pH 6.7 in 1977. The soil is sand throughout the profile, low in organic matter and calcium, and has a low cation exchange capacity. A higher level of calcium, important for nodulation (3,11), would be available at pH 6.7. A higher calcium level is required for *Bradyrhizobium japanicum* (Kirchner) Jordon infection and early nodule development than for mature nodule activity (5).

A pH at the upper limit for optimum soybean growth appears to provide conditions for better nematode control and nutrient availability. These are factors important for good soybean productivity.

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