# Effects of Nematicide Placement on Nematode Populations and Soybean Yields[1]

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*Abstract:* Four methods of placement of DBCP (1,2-dibromo-3-chloropropane) and a single method of application of ethoprop (0-ethyl *S,S*-dipropyl phosphorodithioate) were compared in each of two areas for control of nematodes on soybeans. One area was a Marlboro sand infested with *Hoplolaimus columbus.* The other area was a Fuquay loamy sand infested with *Meloidogne incognita.* Soybean yields were increased and numbers of *H. columbus* in the row 0–20 cm deep were decreased similarly by all methods of DBCP application in Marlboro soil. All DBCP treatments increased the average soybean yields and decreased numbers of *M. incognita* larvae in the row 0–20 cm deep in the Fuquay soil. Average root-knot indices were reduced by all DBCP treatments except with placement 40 cm deep beneath the row. Similarly, placement of all or part of the DBCP 20 cm deep and 13 cm to either side of the row resulted in greater average yields than placement of the DBCP 40 cm deep. Apparently, control of *M. incognita* is more critical 0–20 cm deep than 20–40 cm deep for increasing soybean yields. DBCP did not control *H. columbus* as effectively as it did *M. incognita.* Control of *H. columbus* and *M. incognita* was not obtained at 0–20-cm and 20–40-cm depths 30 cm and 45 cm from the row regardless of the method used to apply DBCP. *H. columbus* and *M. incognita* were controlled more effectively and soybean yields were higher with DBCP at 13.6 kg a.i./ha than with ethoprop at 4.5 kg a.i./ha. *Key Words: Glycine max, Meloidogyne incognita, Hoplolaimus columbus,* root-knot nematode, lance nematode, DBCP, ethoprop.

Subsoiling and nematicide application in the planting row are being used increasingly for soybean (*Glycine max*) production in the United States. Yields may be improved by these practices on compacted soil infested with nematodes (7, 8). Application of liquid fumigant 30–40 cm deep behind the subsoiling shank has become standard practice on some farms. DBCP (1,2-dibromo-3-chloropropane) has been the fumigant used most commonly. Where subsoiling is

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not practiced, DBCP is usually injected 15–20 cm deep. Research conducted several years ago in California on sandy soil that had not been subsoiled indicated that placement of DBCP 15–20 cm deep was probably best for most purposes (4). When the depth of injection was increased to 25–30 cm, control near the surface was decreased. The same workers (5) found that in 9 weeks DBCP placed 20 cm deep moved horizontally and down vertically 38 cm from the point of injection. Bernard and Hussey (1) reported that the presence of a layered soil in middle Georgia and the practice of subsoiling to disrupt plow pan complicated the movement of DBCP. Lateral movement was greater at 0–30 cm deep than at 30–50 cm deep. The rate of lateral movement varied with dose, depth of application, and whether the soil was subsoiled.

We compared four methods of placement of DBCP and a single method of application of ethoprop (0-ethyl *S,S*-dipropyl phosphorodithioate) in each of two areas for control of nematodes on soybeans.

## MATERIALS AND METHODS

Experiments were conducted on a Marlboro sand infested with *Hoplolaimus columbus* Sher at Midville, Georgia, in 1974 and 1975, and on a Fuquay loamy sand infested with *Meloidogyne incognita* (Kofoid & White) Chitwood at Tifton, Georgia, in 1975 and 1976. Experiments were run both years on the same sites at each location. The Marlboro sand (top soil) was 90% sand, 4% silt, and 6% clay; and the Fuquay loamy sand (top soil) was 88% sand, 8% silt, and 4% clay.

At Midville the soil was disked twice to a depth of 10 cm, treated with the herbicide vernolate (*S*-propyl dipropylthiocarbamate) at 2.24 kg/ha, and rototilled 7.5 cm deep. Beds 13–15 cm high were formed with a subsoiler and lister-bedder, and were smoothed with a combination rototiller-leveling device. The subsoiler chisels ran 40 cm deep under the intended row.

At Tifton a root-knot-nematode-susceptible winter legume, hairy vetch (*Vicia villosa* Roth), was grown to increase the nematodes. The soil was plowed to a depth of 25 cm with a moldboard plow. After plowing, beds 13–15 cm high were formed and subsoiler chisels were run in the beds directly under the intended row. After subsoiling a power-driven rototiller was used to smooth the beds and incorporate the herbicide, trifluralin (a,a,a-trifluoro-2,6-dinitro-*N,N*-dipropyl-p-toluidine), to a depth of 8 cm.

DBCP at 13.6 kg a.i./ha or ethoprop at 4.5 kg a.i./ha was applied in the prepared seedbeds. Treatments were: 1) DBCP injected with one chisel in the row 40 cm deep (R40); 2) DBCP injected with three chisels per row, one in the row 40 cm deep and one 13 cm to either side of the row 20 cm deep (R40S20-20); 3) DBCP injected with one chisel in the row 20 cm deep (R20); 4) DBCP injected with two chisels per row, one 13 cm to either side of the row 20 cm deep (S20-20); 5) ethoprop applied in a 45-cm-wide band over the row and incorporated 10–15 cm deep (B10-15); and 6) an untreated control. The experimental design was a randomized complete block, replicated six times at Midville both years, six times at Tifton in 1975, and four times at Tifton in 1976. The plots at Midville were 9.1 m long, four rows wide spaced 0.96 m apart, and the plots at Tifton were 6.1 m long, four rows wide spaced 0.9 m apart.

At Midville nematicides were applied on 2 May 1974 and 14 May 1975, and soybeans were planted on 7 May 1974 and 28 May 1975. At Tifton nematicides were applied on 9 May 1975 and 20 May 1976, and soybeans were planted on 12 May 1975 and 21 May 1976. 'McNair 800' soybean was planted at 33 seeds/m of row in all tests. Weeds not controlled by herbicides were destroyed by cultivation and hand-weeding. Insects were controlled with insecticides.

Nematode populations were monitored at depths of 0–20 and 20–40 cm in the row and 15, 30, and 45 cm from the row. At Midville, soil samples were collected on 18 June and 29 July 1974; and on 17 June and 30 September 1975. At Tifton, soil samples were collected on 10 June and 26 September 1975; and on 22 June and 22 September 1976. Soil was collected with a 7-cm-diam × 16.5-cm-deep bucket auger from the two outside rows of each plot. Five soil cores from each plot were placed in a pail and mixed well, and a 500-$cm^3$ subsample was withdrawn for assay. Each sample contained soil from only the depth zone indicated.

Nematodes were extracted from 150 $cm^3$ of soil by the centrifugation-sugar flotation method (6). At Tifton, roots of 10 plants from the 2 outside rows of each four-row plot were rated for galling 17 weeks after planting. Root-knot ratings were based on a scale of 1–5: 1 = no galling, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of root system galled. Plant heights and yields were obtained from the two center rows of each plot. The data were subjected to analysis of variance and Duncan's multiple-range test (9).

## RESULTS

Yields of soybeans grown on Marlboro sandy loam infested with *H. columbus* were not affected by the method of DBCP placement (Table 1). Yields in both years were greater from plots of all DBCP treatments than from ethoprop and control plots. Yields from plots treated with ethoprop were similar to those of the control in 1974. In 1975, however, when yields from both treatments were extremely low, yields were greater from ethoprop-treated plots than from control plots. The same relative differences among treatments for yield also existed for plant height. Symptoms of *H. columbus* injury occurred in the early stages of growth and persisted throughout the growing season.

Population levels of *H. columbus* in the row and 15 cm from the row in relation to treatments are shown for 29 July 1974 and 30 September 1975 (Table 2). Since these data are similar to data collected earlier each year, the data collected earlier are not shown. Also, treatments generally did not reduce nematode population levels 30 and 45 cm from the row, and these data are not shown.

Population levels of *H. columbus* on 29 July 1974 and on 30 September 1975 in the row at depths of 0–20 cm and 20–40 cm were significantly less in all DBCP-treated plots than in control plots (Table 2). Differences among DBCP treatments were not significant at the 0–20-cm depth, but at 20–40-cm depth there were fewer nematodes in R40 and R40S20-20 plots than in S20-20 plots on 29 July 1974. There were also fewer nematodes at the 20–40-cm depth in R40 plots than in R20 plots on 30 September 1975. Population levels in the row in 1974 did not differ at 0–20 cm from those at 20–40 cm for any treatment. In 1975 there were fewer nematodes in the row at 0–20 cm than at 20–40 cm in R20, ethoprop, and the control plots.

Population differences among treatments also occurred 15 cm from the row on 29 July 1974 and 30 September 1975. In 1974 the population levels were reduced at 0–20 cm in R40S20-20 and S20-20 plots, whereas in 1975 no treatment reduced the numbers at 0–20 cm. All DBCP treatments in 1974 and all but the S20-20 treatment in 1975 reduced numbers at 20–40 cm. In 1974 there were fewer nematodes at 20–40 cm than at 0–20 cm in all except the R40S20-20 and S20-20 plots. In 1975 the R20 plots had fewer nematodes at 20–40 cm than at 0–20 cm.

Yields in 1975 were not significantly affected by the method of DBCP placement in Fuquay soil infested with *M. incognita* (Table 3). Yields in 1976 were greater in R40S20-20 and S20-20 plots than in R40 plots. Yields were also greater in S20-20 plots than in R20 plots. All DBCP plots yielded more than did ethoprop plots in

TABLE 1. Influence of DBCP placement and ethoprop on yield and height of soybeans grown on Marlboro soil infested with *Hoplolaimus columbus*.[a]

| Chemicals | Placement | Yield (kg/ha) 1974 | Yield (kg/ha) 1975 | Yield (kg/ha) Av | Height (cm) 1974 | Height (cm) 1975 | Height (cm) Av |
|---|---|---|---|---|---|---|---|
| DBCP | R40 | 2003 a | 1761 a | 1882 a | 95 a | 80 a | 85 a |
| DBCP | R40S20-20 | 1996 a | 1740 a | 1868 a | 92 a | 84 a | 88 a |
| DBCP | R20 | 1841 a | 1452 a | 1646 a | 92 a | 84 a | 88 a |
| DBCP | S20-20 | 1801 a | 1700 a | 1754 a | 89 a | 87 a | 91 a |
| Ethoprop | B10-15 | 1431 b | 672 b | 1055 b | 69 b | 50 b | 59 b |
| Control | | 1236 b | 296 c | 776 c | 67 b | 36 c | 52 b |

[a]Data followed by the same letter in columns are not significantly different (P = 0.05) according to Duncan's multiple-range test.

TABLE 2. Effect of DBCP placement and ethoprop on average numbers of *Hoplolaimus columbus*/150 cc soil.

| | | Sampling date and sample depth | | | |
|---|---|---|---|---|---|
| | | 29 July 1974 | | 30 September 1975 | |
| Chemicals | Placement | 0–20 cm | 20–40 cm | 0–20 cm | 20–40 cm |
| | | In row[a] | | | |
| DBCP | R40 | 253 b | 40 c | 481 b | 368 c |
| DBCP | R40S20-20 | 176 b | 68 c | 429 b | 505 bc |
| DBCP | R20 | 81 b | 256 bc | 389 b | 1156 b |
| DBCP | S20-20 | 197 b | 373 b | 307 b | 635 bc |
| Ethoprop | B10-15 | 529 a | 391 b | 1091 a | 1885 a |
| Control | | 652 a | 776 a | 1209 a | 1811 a |
| | | 15 cm to side of row[a] | | | |
| DBCP | R40 | 636 ab | 124 c | 268 b | 255 bc |
| DBCP | R40S20-20 | 296 b | 153 bc | 457 b | 189 c |
| DBCP | R20 | 731 a | 341 b | 969 a | 337 bc |
| DBCP | S20-20 | 275 b | 200 bc | 531 b | 499 ab |
| Ethoprop | B10-15 | 627 ab | 267 bc | 544 b | 633 a |
| Control | | 990 a | 537 a | 619 b | 765 a |

[a]Data underscored by the same line in rows or followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

1975, but in 1976 only the S20-20 plots yielded more than ethoprop. The 2-year average yields were greater in the R40S20-20 and S20-20 plots than in the R40 plots. All DBCP treatments except R40 yielded more than ethoprop, and ethoprop yielded more than control.

In both years, plant heights were greater for all chemical treatments than for the control (Table 3). The method of DBCP placement did not affect plant heights, but in 1975 the plants were shorter in the ethoprop plots than in all DBCP plots except R40.

Root-knot indices in 1975 were reduced by all treatments although the reductions were not as great for the R40 and ethoprop treatments as for the other DBCP treatments (Table 4). In 1976, root-knot indices for R40 and R20 treatments did not differ significantly from the control. Reductions occurred in all other plots.

Population levels of *M. incognita* in the row and 15 cm from the row in relation to treatments are shown for 26 September 1975 and 22 September 1976 (Table 5). Since these data are similar to those collected earlier each year, the data collected earlier

TABLE 3. Influence of DBCP placement and ethoprop on yield and height of soybeans grown on Fuquay soil infested with *Meloidogyne incognita*.[a]

| | | Yield (kg/ha) | | | Height (cm) | | |
|---|---|---|---|---|---|---|---|
| Chemicals | Placement | 1975 | 1976 | Av | 1975 | 1976 | Av |
| DBCP | R40 | 2412 a | 2090 cd | 2251 bc | 78 ab | 88 a | 83 a |
| DBCP | R40S20-20 | 2748 a | 2755 ab | 2755 a | 82 a | 89 a | 86 a |
| DBCP | R20 | 2715 a | 2305 bc | 2507 ab | 83 a | 91 a | 87 a |
| DBCP | S20-20 | 2688 a | 2984 a | 2836 a | 81 a | 85 a | 83 a |
| Ethoprop | B10-15 | 1579 b | 2392 bc | 1989 c | 69 b | 95 a | 82 a |
| Control | | 1297 b | 1646 d | 1472 d | 55 c | 71 b | 63 b |

[a]Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

TABLE 4. Effect of DBCP placement and ethoprop on root-knot index of soybean plants.

| Chemicals | Placement | Root-knot index[a] 1975 | 1976 | Av |
|---|---|---|---|---|
| DBCP | R40 | 4.1 b | 5.0 a | 4.4 a |
| DBCP | R40S20-20 | 2.2 c | 2.6 bc | 2.4 c |
| DBCP | R20 | 1.6 c | 4.3 a | 2.7 c |
| DBCP | S20-20 | 2.1 c | 2.1 c | 2.1 c |
| Ethoprop | B10-15 | 3.4 b | 3.1 b | 3.3 b |
| Control | | 5.0 a | 4.6 a | 4.8 a |

[a]Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

are not shown. Also, treatments generally did not reduce nematode population levels 30 cm and 45 cm from the row, and these data are not shown.

Population levels of *M. incognita* larvae on 26 September 1975 and 22 September 1976 in the row at 0–20 cm were significantly less in all DBCP plots than in the control plots (Table 5). There were no statistically significant differences among DBCP plots at 0–20 cm in 1975, whereas in 1976 there were fewer nematodes in R40S20-20 and S20-20 plots than in R40 plots. At 20–40 cm in 1975 fewer nematodes were present in R40, R40S20-20, and R20 plots than in S20-20, ethoprop, and control plots while in 1976 no differences existed. Population levels of 26 September 1975 in the row were lower at 20–40 cm than at 0–20 cm for R40 and control, but population levels for S20-20 were greater at 20–40 cm than at 0–20 cm. Also, population levels on 22 September 1976 in the row were lower at 20–40 cm than at 0–20 cm for R40 and R20 treatments and the control.

*M. incognita* larvae 15 cm from the row at 0–20 cm were reduced by all DBCP treatments except R40 on 26 September 1975, but differences were not significant on 22 September 1976. Control was significant also at 20–40 cm for all treatments in 1975 but not in 1976. In 1975, population levels were lower at 20–40-cm depth than at 0–20 cm for the ethoprop treatment and control, but no differences occurred in 1976. Although *M. incognita* populations were arithmetically lower in most chemical treatments than in the control in 1976, these differences were not statistically significant because of variability within treatments.

## DISCUSSION

Soybean yields were increased similarly

TABLE 5. Effect of DBCP placement and ethoprop on average numbers of *Meloidogyne incognita* larvae/150 cc of soil.

| Chemicals | Placement | Sampling date and sample depth: 26 September 1975, 0–20 cm | 26 September 1975, 20–40 cm | 22 September 1976, 0–20 cm | 22 September 1976, 20–40 cm |
|---|---|---|---|---|---|
| | | In row[a] | | | |
| DBCP | R40 | 477 bc | 17 b | 586 b | 30 a |
| DBCP | R40S20-20 | 105 c | 19 b | 154 cd | 8 a |
| DBCP | R20 | 15 c | 9 b | 384 bc | 18 a |
| DBCP | S20-20 | 87 c | 534 a | 27 d | 100 a |
| Ethoprop | B10-15 | 930 ab | 711 a | 298 c | 224 a |
| Control | | 1368 a | 541 a | 954 a | 192 a |
| | | 15 cm to side of row[a] | | | |
| DBCP | R40 | 233 bc | 5 c | 190 a | 183 a |
| DBCP | R40S20-20 | 4 c | 3 c | 24 a | 22 a |
| DBCP | R20 | 8 c | 5 c | 140 a | 40 a |
| DBCP | S20-20 | 7 c | 32 bc | 4 a | 16 a |
| Ethoprop | B10-15 | 733 a | 108 b | 204 a | 196 a |
| Control | | 528 ab | 192 a | 202 a | 152 a |

[a]Data underscored by the same line in rows or followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

by all methods of DBCP placement in Marlboro soil infested with *H. columbus*. Differences in nematode control among DBCP treatments were apparently too small to affect yields. However, placement of the fumigant affected yields and control of *M. incognita* in Fuquay soil. In general, both were poorer when all of the DBCP was placed 40 cm deep in Fuquay soil than when part or all was placed 20 cm deep. These results corroborate results of Gilpatrick et al. (4), who found that nematode control near the surface was less with DBCP placed 25–30 cm deep than with shallower placement. Control of *M. incognita* for increasing soybean yields is apparently more critical 0–20 cm deep than 20–40 cm deep.

DBCP did not control *H. columbus* as effectively as it controlled *M. incognita*, corroborating earlier results (8). One or more stages of the life cycle of *H. columbus* apparently tolerated the DBCP dose used. Perhaps the adult *H. columbus* survived, which could greatly affect the survival ratio of *H. columbus* to *M. incognita*. When treatments were applied, all stages of *H. columbus* were free in the soil, and only males, larvae, and eggs of *M. incognita* were free. Chitwood (2) observed that immature forms of nematodes were killed by nematicides more readily than were mature forms. Evans and Thomason (3) found that larval stages of *Aphelenchus avenae* Bastian were killed by ethylene dibromide (1,2-dibromoethane) more easily in the molt than in nonmolting stages, and that susceptibility differed among species.

Control of *H. columbus* and *M. incognita* was not obtained at 0–20-cm and 20–40-cm depths 30 cm and 45 cm from the row regardless of the method used to apply DBCP. This indicated that the effectiveness of DBCP diminished rapidly laterally from the point of injection.

*H. columbus* and *M. incognita* were controlled more effectively, and soybean yields increased more, with DBCP at 13.6 kg a.i./ha than with ethoprop at 4.5 kg a.i./ha.

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