

Soybean Yield as Related to Rates of 1,3-Dichloropropene Applied at Planting for Management of Root-Knot Disease¹

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Abstract: 1,3-Dichloropropene (1,3-D) at rates of 17.2 to 51.6 liters/ha applied 3 days preplant or at planting significantly ($P < 0.05$) reduced the amount of galling on roots of soybean grown in sites infested with *Meloidogyne incognita* or *M. arenaria*. Populations of *M. incognita* second-stage juveniles at harvest were significantly ($P < 0.05$) reduced by all treatments. Only the 51.6-liters/ha treatments and a 3-day preplant 34.4-liters/ha application significantly reduced at-harvest juvenile infestations of *M. arenaria*. Equations ($P < 0.001$) relating soybean yield and 1,3-D dosage indicated soybean phytotoxicity at the upper range of the nematicide rates. The maximum yield response was predicted at 40 liters/ha applied 3 days preplant at both infestation sites. Maximum yield response was predicted with 30 liters/ha applied at planting to *M. incognita*-infested soil and from 25 liters/ha applied at planting to *M. arenaria*-infested soil. Application of economic factors suggested that management of *M. incognita* may be cost effective with at-plant treatments of low rates of 1,3-D. Yield responses of *M. arenaria*-infested soybean exposed to similar treatments were insufficient to justify their use at prevailing prices.

Key words: *Meloidogyne incognita*, *Meloidogyne arenaria*, nematicide, *Glycine max*.

The root-knot nematodes *Meloidogyne incognita* (Kofoid and White) Chitwood and *M. arenaria* (Neal) Chitwood are widespread pathogens of soybean, *Glycine max* (L.) Merr., in the southern United States. Nonfumigant nematicides have not been as successful as the fumigants in their management (5,8). Planting-time injections of low rates (10–20 liters/ha) of dibromochloropropane or dibromoethane have been cost effective (6). Removal of these hazardous nematicides has left 1,3-dichloropropene (1,3-D) as the only fumigant nematicide currently labelled for use on soybean in the United States. It has not been widely used in soybean production.

Label restrictions for the use of 1,3-D on field crops require application at rates of 46–72 liters/ha (0.9 m-row spacing) followed by exposure and aeration periods that may total 10–20 days before planting. Application costs prohibit the use of 1,3-D in a low value crop such as soybean. The bulk of material to be applied per hectare and the delay between injection and planting have also contributed to the lack of acceptance of this nematicide by soybean growers. In addition, the long period be-

tween soil preparation and planting, at a time (May–June) of considerable rainfall in the southeast, exposes the soil to potential erosion. Consequently, studies have been conducted to evaluate the efficacy of applying 1,3-D at planting to manage nematode diseases of soybean. At a site infested with *M. arenaria*, all treatments in excess of 20 liters/ha, in a range of 10.3–77.5 liters/ha, increased yields with maximum yield response at 46.3 liters/ha (10). At a site infested with *Hoplolaimus columbus* Sher, maximum yield response was from a treatment of 34 liters/ha in a range of 17–68 liters/ha (2). These results indicate a yield-dosage relationship with a peak response within the range of 30–50 liters/ha and suggest a phytotoxic effect at current labelled rates when applied at time of planting.

My objectives were to determine the relationships between soybean yield and low rates of 1,3-D when the nematicide is applied 3 days before planting and at planting (application delays shorter than the current recommendations) for the management of root-knot disease and, by applying economic factors, to determine the cost effectiveness of these treatments.

MATERIALS AND METHODS

Experiments were conducted at a site infested with *M. incognita* at the University of Florida Agricultural Research and Ed-

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TABLE 1. Root-knot galling, juvenile density at harvest, and yield of soybean in soil treated with 1,3-dichloropropene applied 3 days before planting (B) and at planting (A).

Rate (liters per ha)	Time	Galling*		Juveniles/10 cm ³ soil		Yield (kg/ha)	
		Mi	Ma	Mi	Ma	Mi	Ma
0		3.1 a	2.1 a	410 a	80 ab	2,006 c	1,199 c
17.2	B	1.2 bc	0.8 cd	112 c	77 ab	2,667 ab	1,470 ab
	A	1.6 b	1.5 b	197 b	110 a	2,790 ab	1,413 abc
25.8	B	0.6 cd	0.4 cde	88 cd	47 bcd	2,764 ab	1,561 a
	A	1.4 b	1.0 bc	114 c	69 abc	2,811 a	1,589 a
34.4	B	0.2 d	0.0 e	55 cd	23 d	2,898 a	1,593 a
	A	0.5 cd	0.3 de	21 d	44 bcd	2,771 ab	1,383 bc
51.6	B	0.3 d	0.1 de	40 cd	14 d	2,837 a	1,571 a
	A	0.2 d	0.1 de	11 d	34 cd	2,492 b	1,260 cd

Averages followed by the same letter within a column are not significantly different ($P < 0.05$) according to Duncan's multiple-range test.

* Rated on a scale of 0 = no galling, 0.2 = < 5%, 1 = 6-25%, 2 = 26-50%, 3 = 51-75%, 4 = > 75% of the root surface galled. Mi = *Meloidogyne incognita*. Data are averages of 9 replicates. Ma = *Meloidogyne arenaria*. Data are averages of 10 replicates.

ucation Center, Jay, Florida, and at a site infested with *M. arenaria* at the Davis Farm, Santa Rosa County, Florida. Soils at both sites were sandy loams (70% sand, 15% silt, 15% clay), typical of soils throughout the Southern Coastal Plain of the United States.

The fumigant 1,3-D was injected with a single chisel at rates of 0, 17.2, 25.8, 34.4, and 51.6 liters/ha to a depth of 0.45 m in soil that was bedded simultaneously. These rates were applied 3 days before planting (12 June) and immediately before planting. The treatments were arranged in a randomized design and applied to plots 15 m long with four rows spaced 0.9 m apart. The treatments were replicated 9 times at the *M. incognita* site and 10 times at the *M. arenaria* site. The tops of the beds were levelled by a board sweep at planting, and the seeds were positioned 0.35 m above the site of 1,3-D injection. The *M. incognita* site was planted with 'Ransom' soybean, a susceptible cultivar, and the *M. arenaria* site was planted with 'Kirby', a cultivar with the most resistance to this nematode.

In August, when the soybean plants had reached the V12-V13 vegetative stage of development (3), four groups of plants, each consisting of 4-5 plants, were removed from the border rows of each plot and rated for the amount of root-knot galling according to a scale of 0 = no galling, 0.2 = < 5%, 1 = 6-25%, 2 = 26-50%, 3 = 51-75%, and 4 = > 75% of the root sur-

face galled. The two center rows of each plot were harvested at maturity, and the seed yield was converted to kg/ha at 13% seed moisture.

Immediately following harvest, all plots were sampled for infective second-stage juveniles. Soil cores, 2.5 × 17 cm, were taken every meter of harvested row. The cores were bulked for each plot, and 100 cm³ soil was processed using the sugar centrifugal-flotation technique (4). Nematodes were counted on a gridded dish and recorded as juveniles per 10 cm³ soil.

RESULTS

All 1,3-D treatments resulted in levels of root-knot galling lower than those in nontreated soybean plots (Table 1). Root-knot galling in the nontreated plots at the *M. arenaria* site was less than that in similar plots at the *M. incognita* site. This probably reflects the relative susceptibility of the cultivars to the nematodes. Where 1,3-D was applied, however, galling was comparable between dosage rates at both sites. Roots from the 3-day preplant tended to be less galled than those from at-plant treatments. Differences were significant ($P < 0.05$) with the 17.2-liters/ha and 25.8-liters/ha treatments at the *M. arenaria* site and with the 25.8-liters/ha treatment at the *M. incognita* site. Galling at both sites was slight with the 34.4-liters/ha and 51.6-liters/ha treatments. The significance of

the relationships between the amount of root-knot galling (Y) and the dosage rate of 1,3-D (X) follows:

M. incognita

Three-day preplant:

$$Y = 3.13 - 0.14X + 0.0017X^2$$

$$R = 0.79 (P < 0.002)$$

At planting:

$$Y = 2.84 - 0.06X$$

$$r = 0.76 (P < 0.0001)$$

M. arenaria

Three-day preplant:

$$Y = 2.12 - 0.10X + 0.0011X^2$$

$$R = 0.72 (P < 0.006)$$

At planting:

$$Y = 2.09 - 0.04X$$

$$r = 0.62 (P < 0.0002)$$

All treatments applied to the *M. incognita* site reduced the number of juveniles present in the soil at harvest (Table 1). The relationships between juvenile numbers per 10 cm³ soil (Y) and the amount of 1,3-D applied (X) were significantly related and are described thus:

Three-day preplant:

$$Y = 399.52 - 18.4X + 0.225X^2$$

$$R = 0.81 (P < 0.0009)$$

At planting:

$$Y = 416.16 - 16.25X + 0.16X^2$$

$$R = 0.84 (P < 0.005)$$

At the *M. arenaria* site, only the 3-day preplant treatment of 34.4 liters/ha and both the 51.6-liters/ha treatments reduced juvenile numbers below those in the nontreated plots (Table 1). There were no relationships between incidence of juveniles at harvest and the amount of 1,3-D applied at the *M. arenaria* site.

All treatments increased ($P < 0.05$) yields at the *M. incognita* site (Table 1). The relationships between yield (Y) and the amount of 1,3-D applied (X) are described thus:

Three-day preplant:

$$Y = 2,015.57 + 45.19X - 0.57X^2$$

$$R = 0.72 (P < 0.003)$$

At planting:

$$Y = 2,034.37 + 53.48X - 0.87X^2$$

$$R = 0.66 (P < 0.0005)$$

At the *M. arenaria* site, all treatments, with the exception of 51.6 liters/ha applied at planting, increased ($P < 0.05$) yields

over nontreated plots. The relationships between yield (Y) and the amount of 1,3-D (X) applied are described thus:

Three-day preplant:

$$Y = 1,198.94 + 20.37X - 0.27X^2$$

$$R = 0.73 (P < 0.002)$$

At planting:

$$Y = 1,200.47 + 21.18X - 0.39X^2$$

$$R = 0.51 (P < 0.001)$$

DISCUSSION

Equations describing the relationships between yield and 1,3-D dosage predict that 3-day preplant treatments would produce maximum yield responses at a dosage of 40 liters/ha at both the *M. incognita* and the *M. arenaria* sites. Maximum yield responses from the planting-time treatments would occur at 25 liters/ha at the *M. arenaria* site and at 30 liters/ha at the *M. incognita* site. These rates are all below current label recommendations for nematode management on soybean.

Soybean yield in the presence of root-knot nematode is inversely related to the amount of root-knot galling the plant suffers (7); it is apparent the higher rates of 1,3-D used in this study were phytotoxic since they produced significantly lower root-knot galling responses. Phytotoxic effects would explain the lower dosage required for maximum yield response from treatment at planting than that required from treatment applied 3 days before planting.

Prevailing economic factors must be considered when determining the optimum rates of nematicidal treatments. Data are presented using prices for 1,3-D (\$2.53/liter) and soybean seed value (\$0.22/kg) available in January 1985 (Table 2). These indicate that maximum profit from the 3-day preplant treatment at the *M. incognita* site would be from 30 liters/ha, and from 25 liters/ha at planting time. These rates are lower than necessary to produce maximum yield responses.

M. arenaria is more pathogenic than *M. incognita* (1,9), and yield responses at the *M. arenaria* site were insufficient to justify 1,3-D use under prevailing economic conditions. The dosage rate required to produce maximum yield response from the 3-day preplant treatment would result in a net loss, and maximum yield response from

TABLE 2. Economic analyses of soybean yield responses to 1,3-dichloropropene applied 3 days before planting (B) and at planting (A) to root-knot nematode-infested soil.

Rate (liters per ha)	<i>Meloidogyne incognita</i>				<i>Meloidogyne arenaria</i>			
	B		A		B		A	
	Yield increase (kg/ha)	Net profit (\$/ha)	Yield increase (kg/ha)	Net profit (\$/ha)	Yield increase (kg/ha)	Net profit (\$/ha)	Yield increase (kg/ha)	Net profit (\$/ha)
5	212	34	246	41	95	8	96	9
10	395	62	448	73	177	14	173	13
15	550	83	606	95	245	16	230	13
20	676	98	722	108	299	15	268	8
25	773	107	793	111	341	12	286	0
30	843	109	821	105	368	5	284	-13
35	883	106	806	89	382	-4	264	-31
40	896	96	747	63	383	-17	223	-52
45	879	80	645	28	370	-32	163	-78
50	834	57	499	-17	344	-51	84	-108

Based on prices of 1,3-D at \$2.53/liter and soybean at \$0.22/kg, January 1985.

the planting-time treatment just covers the cost of nematicidal treatment. At soil infestation levels used in this study, *M. arenaria* may be too damaging a species on soybean to warrant at-plant applications of 1,3-D for its management unless the value of soybean were to increase greatly.

These studies were conducted under optimum moisture conditions between time of treatment through soybean germination and establishment of the crop. Excessive rainfall at this period may make planting-time treatments of 1,3-D less appealing because of the possibility of increasing phytotoxic effects. However, these data suggest, that at sites infested with *M. incognita*, a reduction in the dosage rate of 1,3-D below the range of recommended treatments and a shortening of the waiting period between treatment and planting may be an option for management of this nematode on soybean.

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