COMPARISON OF DIFFERENT CHISEL TYPES FOR 1,3-DICHLOROPROPENE FUMIGATION IN DEEP SANDY SOILS†

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RESUMEN

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El fumigante nematicida1,3-Dicloropropano (1,3-D), formulado con cloropicrina, es el posible sustituto de bromuro de metilo una vez que éste entre en desuso en el 2005. Este nematicida ha sido usado en Florida para controlar nematodos en muchos cultivos. El método de aplicación es un factor importante que afecta su eficiencia. Se condujo un experimento para evaluar tres tipos de cinceles para aplicar 1,3-D en un campo infectado con *Meloidogyne incognita* y *M. javanica*. Como tratamientos se incluyeron: 1,3-D aplicado en hilera en dosis de 84 litros/ha utilizando cinceles convencionales (con o sin discado), paracinceles (con o sin discado), rastra, y testigo. Se transplantaron plántulas de tomate en las hileras, las cuales se cultivaron por 35 días. Se muestrearon 10 plantas por parcela y se contó el número de juveniles del segundo estado (J2) que penetraron en las raíces. Las fumigaciones con 1,3-D redujeron el número de J2 que penetró en las raíces al compararlas con el testigo ($P < 0.05$). Plantas cultivadas en suelos fumigados con rastra presentó el más alto número de J2 por sistema radical ($P < 0.05$). Rastreo después de la fumigación con cinceles convencionales redujo 4.7 veces los J2 por sistema radical. Rastreo después de la fumigación con cinceles convencionales mejoró ligeramente la acción de 1,3-D y rastreo después de aplicación de 1,3-D con paracinceles aparentemente no afectó el número de J2 que penetró en las raíces.

Palabras claves: Cincel, cincel convencional, 1,3-dicloropropano, fumigante, fumigación, *Lycopersicon esculentum, Meloidogyne incognita, Meloidogyne javanica, Meloidogyne* spp., nematicida, nematodo agallador de raíces, paracincel, rastra, tomate.

A likely replacement for methyl bromide (scheduled for de-registration in 2005) is the fumigant nematicide, 1,3-dichloropropene (1,3-D) formulated with chloropicrin. This nematicide has been used in Florida for control of nematodes on many crops. The method of application is an important factor which affects its efficacy. A major concern with the use of 1,3-D in Florida deep sandy soil is retaining an adequate dosage to provide suitable efficacy while preventing premature emission into the atmosphere. The fumigant is generally applied with conventional chisels, 15 to 20 cm deep, which leave 1-cm to 1.3-cm chisel traces in the soil (Lembright, 1990). Intact chisel traces allow the fumigant to escape rapidly into the atmosphere (Goring, 1957;

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Lembright, 1990). Rollers, cultipackers, press wheels, and other similar equipment may not adequately remove these chisel traces. The label for Telone II (Dow Agro-Sciences LLC, Indianapolis, IN) was changed to address this concern by requiring that 1,3-D be injected at a depth of 30 cm below the final soil surface and that the chisel traces be broken and filled with soil bedding disks following application.

Although 1,3-D has been used successfully to control plant-parasitic nematodes on many crops, its performance is known to vary (Dickson and Hewlett, 1988; Melton, 1996). One factor which may affect its efficacy in deep sandy soils is the method of application. Elimination of chisel traces (Anonymous, 1996; Dallimore, 1955), reduction of number of chisels (Schneider *et al.*, 1995; Sipes *et al.*, 1993), fumigation at different depths (Gan *et al.*, 1998; Rodríguez-Kábana and Robertson, 1987), and application of water to the soil surface after fumigation (Gan *et al.*, 1998) have reduced 1,3-D emissions. The objective of this study was to compare the efficacy of in-row fumigation of 1,3-D with conventional chisels and parachisels (with and without disking), and subsurface hooded sweep chisels to manage *Meloidogyne* spp. in deep sandy soils.

Two field trials were conducted at the same site at the University of Florida Green Acres Agronomy Research Farm in Alachua County, Florida in 1998 and 1999. The site was infested with *M. incognita* (Kofoid and White) Chitwood, and *M. javanica* (Treub.) Chitwood. Tobacco (*Nicotiana tabacum* L.) was planted in the field in spring 1997. Rye, *Secale cereale* L. cv. Wrens Abruzzi, was planted as a winter cover crop in the fall of both 1997 and 1998 and plowed under in the spring. The soil was an Arredondo fine sand (91% sand, 6% silt, 3% clay, and 2.5% organic matter; pH 6.5).

The experimental design was a randomized complete block with six replications. The two-row plots were 9.1 m long with a row spacing of 91 cm. 1,3-Dichloropropene was applied 8 October 1998 and 15 June 1999. Applications with conventional chisels (with and without disking) or parachisels (with and without disking) were made with two chisels per row spaced 22 cm apart centered over each row. 1,3-Dichloropropene was injected 30 cm deep at 84 L/ha (78 ml/chisel/30.5 m of row) into the soil and a 1.8-m-wide, two-gang disk was run through each plot immediately after fumigant injection to cut the soil surface ca. 15 cm deep thereby forming a surface seal and breaking the continuity of chisel traces. The conventional chisels were forward or rear inclined, double beveled blades, and were arranged with one outer swept-forward chisel and one inner swept-back chisel per row (Riegel *et al.*, 2000). Parachisels were rearward inclined, side-wise sloped on a 45° plane, single beveled blades (Riegel, 2001). The subsurface hooded sweep chisels (Dow Chemical Co., Midland, MI) had a flat tip 8003 TeeJet (Spraying Systems Co., Wheaton, IL) spray nozzle mounted under each subsurface hooded sweep (Riegel, 2001). The soil moisture at time of fumigation was 13% in 1998 and 11% in 1999 and the soil temperature at 10 cm deep reached a maximum of 29°C and a minimum of 27°C in both years.

Twelve soil cores (2.5-cm-diam., 20 cm deep) were taken from each plot with a cone-shaped sampling tube at pretreatment (5 October 1998 and 12 June 1999) and at termination of the study (25 November 1998 and 29 July 1999). Soil cores from each plot were combined and nematodes were extracted from a 100 cm^3 subsample by a centrifugal-flotation method (Jenkins, 1964). All plant-parasitic nematodes were counted.

Glyphosate at the labeled rate was applied broadcast on the soil surface 1 week before planting to manage weeds. Halosulfuron was sprayed at the labeled rate 1 week after planting to manage purple and yellow nutsedge that heavily infested the field plots. A rate of 318 kg of 10-10-10 N-P-K fertilizer/ha was applied broadcast and incorporated into the top 10 cm of soil on the day of planting. Supplemental water was applied through overhead irrigation. Tomato seedlings, *Lycopersicon esculentum* Mill. cv. Solarset, were transplanted 31 and 38 cm apart in all plots on 15 October 1998 and 25 June 1999, respectively.

Root systems of the center 10 plants in each plot were removed 35 days after transplanting (DAT) in 1998 and 37 DAT in 1999. Root-knot nematodes that penetrated the tomato root systems were stained (Byrd *et al.*, 1983) and counted.

Data were subjected to analysis by ANOVA and means separated by Duncan's multiple-range test (SAS Institute, Cary, NC). Differences among the number of root-knot nematodes per tomato root system per treatment were compared by orthogonal contrasts. All data were transformed with $\log_e (x + 1)$ before analyses, and all differences reported were significant at $P \leq 0.05$.

No differences among treatments were observed in final soil population densities of *Meloidogyne* spp. ($P > 0.1$; data not shown). Fumigation in 1998 with 1,3-D, regardless of application method, reduced the number of infective juveniles (J2) that entered the root system of plants compared to plants grown in untreated soil (Table 1). Plants from untreated soil had an average of 87 J2/root system, whereas those from fumigated soil showed an average of 19 J2/root system. The most effective 1,3-D application methods were use of conventional chisels with disking and use of parachisels with and without disking.

1,3-Dichloropropene readily volatilizes in soil and moves from point of injection into open pore spaces in the soil (Goring, 1957). Soil texture, temperature, and moisture may indirectly affect its diffusion pattern and thereby impact efficacy (Thomason and McKenry, 1974). In these trials, the soil temperature and moisture levels before fumigation were considered opti-

Table 1. The number *Meloidogyne* spp. second-stage juveniles (J2) that penetrated 4-week-old tomato seedlings after in-row fumigation with 1,3-dichloropropene applied at 84 liters/ha with conventional chisels (with and without disking), parachisels (with and without disking), and subsurface hooded sweep chisels in 1998 and 1999.

	J2/root system	
Treatment	1998	1999
Untreated	87 a[y]	40[z]
Conventional chisel	8 bc	18
Conventional chisel + disking	2 d	43
Parachisel	5 cd	37
Parachisel + disking	2 d	17
Subsurface hooded sweep chisel	19 b	7

[y]Data presented for all treatments are means of 6 replicates. Data were transformed to $\log_e (x + 1)$ before analysis. Untransformed means in columns followed by the same letter are not significantly different according to Duncan's multiple-range test ($P \leq 0.05$).
[z]Lack of a letter denotes nonsignificance ($P \geq 0.1$).

mum. Although disking after fumigation with conventional chisels increased efficacy, the effect was small. Disking had no effect after fumigation with parachisels because the equipment was designed to apply fumigants in soil without leaving chisel traces (Riegel, 2001). The parachisel blade cuts on a 45° plane from vertical and raises the soil slightly, allowing soil to fall back upon itself after passage of the blade (Riegel, 2001).

1,3-Dichloropropene applied with subsurface hooded sweep chisels was less effective than when applied by conventional chisels or parachisels (Table 1). The subsurface hooded sweep chisel raises the soil 3 to 5 cm as it passes. 1,3-Dichloropropene is sprayed in a 25 cm horizontal stream under the triangular-shaped sweep. Loria *et al.* (1986) and Rhoades *et al.* (1962) reported that fumigants with 1,3-D applied with similar chisels effectively reduced the population densities of plant-parasitic nematodes in the soil compared to the untreated control. Comparison with conventional chisels, however, was inconclusive (Rhoades *et al.*, 1962).

In 1999, no differences among treatments in the number of root-knot nematodes per root system regardless of application method (Table 1). This lack of difference among treatments is similar to what we have experienced in other trials. Even when great care is taken to calibrate and apply 1,3-D properly, there are instances when nematode control following 1,3-D may be less than expected due to a variety of reasons (McKenry and Thomason, 1974). Tolerant life stages of some nematodes (cysts and cryptobiotic stages) in the soil, deep location of nematodes in the soil profile, variation in soil moisture, the presence of restrictive layers in the soil, protection in clumps of soil, and protection in plant tissue such as the tubers of nutsedge (Schroeder *et al.*, 2000) are all factors that may permit escape of plant-parasitic nematodes from effects of fumigation.

It appears that disking to disrupt chisel traces improves performance of 1-3-D slightly when applied in-row, whereas efficacy of 1,3-D applied via parachisels was not affected by disking. The use of the parachisels alone would give the added benefit of decreasing equipment and operation costs to the grower.

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