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Effect of Two Nonfumigant Nematicides on Corn Grown in Two Adjacent Fields Infested with Different Nematodes[1]

D. W. DICKSON AND T. E. HEWLETT[2]

Abstract: The organo-phosphate experimental nematicide, *O*-ethyl S,S-di-sec-butyl phosphorodithioate (FMC 67825), provided yield increases of corn comparable to carbofuran. Both the emulsifiable concentrate and granular formulations of FMC 67825 were equally effective. The evaluations, duplicated in two adjacent fields, clearly demonstrated the importance of the type of plant pathogenic nematodes infesting the sites. Where *Belonolaimus longicaudatus* occurred, yield increases ranged from 73% to 80%, whereas in the adjacent field (without *B. longicaudatus*) yields increases ranged from −14% to 28%.

Key words: *Belonolaimus*, carbofuran, corn, *Criconemella*, FMC 67825, lesion nematode, *Meloidogyne*, nematicide, *Paratrichodorus*, *Pratylenchus*, ring nematode, root-knot nematode, sting nematode, stubby-root nematode, *Zea mays*.

Field corn is the host of several important nematode pests in Florida sandy soils. Infestations of sting (*Belonolaimus* sp.) and stubby-root (*Paratrichodorus* sp.) can result in extensive corn yield losses (1,2). The effect of lesion (*Pratylenchus* spp.) nematodes on corn is not as well documented. Successful and economic control of nematodes on corn has been demonstrated using several different nematicides (3,4,7,11). Because of environmental issues confronting the use of soil-applied insecticide–nematicides, however, there is a need to continually seek out new and safer materials. The purpose of this study was to compare the efficacy of carbofuran with that of an experimental nematicide, *O*-ethyl S,S-di-sec-butyl phosphorodithioate (FMC 67825), on nematode populations and corn yield.

MATERIALS AND METHODS

The investigation was conducted in 1986 on two adjacent fields on the agronomy farm, University of Florida. The south field had been planted with corn in the spring and rye in the winter for for the preceding 9 years. The north field had been planted with sorghum in the spring and rye in the winter for the preceding 3 years, except in 1984 when corn was planted in the spring. The south field was infested with *Belonolaimus longicaudatus* Rau, *Paratrichodorus christiei* Allen, *Pratylenchus brachyurus* (Godfrey) Filipjev & Stekhoven, and *Criconemella ornata* (Raski) Luc & Raski. The north field was infested with *P. christiei*, *P. brachyurus*, *C. ornata*, and *Meloidogyne incognita* (Kofoid & White) Chitwood.

The soil in both fields was an Arredondo fine sand (89% sand, 6% silt, 5% clay, 1.1% organic matter; pH 6.2). The fields were plowed in early March. Identical nematicide treatments were applied to both fields at-plant. Corn (*Zea mays* L. 'Pioneer X304C') was seeded on 9 April at the rate of 90–110 seeds per 12 m of row with rows spaced 76 cm apart. Treatments were arranged in a randomized complete block design and consisted of four rows each 12 m long with the center two rows treated. Each treatment was replicated five times. Carbofuran and FMC 67825 were applied with an electric powered Gandy applicator (Gandy Company, Owatonna, MN) in an 18-cm band directed behind the opening shovel and in front of the planter shoe. The 6EC formulation of FMC 67825 was applied with a CO_2 sprayer in an 18-cm band over the row in 187 liter/ha of water at 1.41 kg/cm^2. In each of the fields two treatments of FMC 67825 were covered with 1-mil plastic after planting and just before the initial irrigation of the fields to test the effect of irrigation on the phyto-

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[1] Florida Agricultural Experiment Station Journal Series No. 8086.

[2] Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611.

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toxicity of FMC 67825 to corn. The plastic was removed from the plots the following morning. The soil temperature at the time of nematicide application averaged 23 C at 15 cm deep and soil moisture was at 60–70% field capacity.

The fields were fertilized with 27.3 kg/ha N, 54.6 kg/ha P_2O_5, 81.5 kg/ha K_2O, 22.5 kg/ha Mg, and 30.3 kg/ha S as a preplant application and with 168 kg/ha NH_4NO_3 and 129 kg/ha K_2SO_4 applied 4 weeks after planting. Weed control consisted of butylate 5.2 liter/ha and atrazine 2.4 liter/ha applied 7 April and incorporated into the soil with a cultivator designed for herbicides. The fields were cultivated twice to maintain weed control.

Rainfalls were frequent with a total of 55 cm of rainfall recorded during the period of the experiment. Overhead sprinkler irrigation was used throughout the experiment as needed. Following germination, the plant stand in each plot was thinned by hand to leave one plant every 20–25 cm.

Soil samples for nematode assay were collected at 71 and 139 days after planting. The center two rows of each plot were sampled in the corn rhizosphere 15 cm deep with a cone-shaped sampling tube (2.5 cm d). A sample consisted of 10 cores composited from each plot. Samples were placed in 0.5-mil plastic bags and stored at 10 C until processed during a 5-day period after sampling. A 250-cm^3 aliquot of each sample was processed by a sugar-flotation-centrifugation method (6). Root samples, consisting of bulked roots from three plants randomly dug from each of the two middle rows of each treatment, were assayed after harvest (15 September). Ten grams of roots from each sample were processed for lesion nematodes (5).

All plots were hand harvested 12 September. Stalks and ears from the two middle rows of each treatment were counted, and the total ear weight was determined. Grain yields are reported as kilograms of shelled corn per hectare at 15.5% moisture. The data were analyzed using analysis of variance, and treatment means were compared by Duncan's new multiple-range test.

Results and Discussion

Fifteen days after planting, symptoms of nematode damage were observed in the south field (Table 1). These included less growth, reduced stands, wilting, and greatly abbreviated roots in the control plots and border rows. No comparable symptoms were observed in the north field (Table 2). The seedlings from plots that were covered with plastic in both fields had yellow leaves and were wilted for a few days, after which they recovered.

All treatments in the south field had significantly greater numbers of stalks and ears and higher yields than the untreated control (Table 1). Yields from treated plots averaged 4,372 to 6,154 kg/ha more than yield from the untreated control, but there were no significant differences among yields from treated plots. FMC 67825 provided nematode control on corn that resulted in large yield increases where sting nematode was the dominant pathogen (Table 1). Its performance on yield was comparable to that of carbofuran. FMC 67825 performed well when applied either as emulsifiable concentrate or granular formulation.

All treatments of FMC 67825 had significantly ($P = 0.05$) lower numbers of stubby-root and sting nematodes than the control at harvest; however, there was no significant reduction in the numbers of ring, root-knot, or lesion nematodes in either soil or roots (Table 1). Correlation coefficients showed significant ($P = 0.05$) inverse relationships between numbers of stubby-root nematodes per 250 cm^3 soil at harvest and numbers of ears ($r = -0.45$), stalks ($r = -0.47$), or yield ($r = -0.37$). Numbers of sting nematodes at harvest were also inversely related ($P = 0.05$) to yield ($r = -0.28$).

FMC 67825 applied at 8.5 g a.i./100 m was the only treatment in the north field that yielded significantly more than the control (7,823 kg/ha or 28% increase) (Table 2). There was a significant ($P = 0.05$) inverse correlation between yield and

TABLE 1. Corn yield, plants and ears per treatment at harvest and average number of nematodes per 250 cm^3 soil at Pm and Pf and lesion nematodes per g roots at Pf as affected by treatment of nematicides in the south field.

Treatments	Rate of active ingredient/ 18-cm band (broadcast rate)†	Yield kg/ha	Plants	Ears	Soil										Roots
					Paratrichodorus		*Belonolaimus*		*Pratylenchus*		*Criconemella*		*Meloidogyne*		*Pratylenchus*
					71 days	139 days	71 days	139 days	71 days	139 days	71 days	139 days	71 days	139 days	159 days
Carbofuran	11.4 g/100 m (3.7 kg/ha)	7,741 a	83 a	86 a	4 a	24 ab	176 a	134 ab	8 a	162 a	398 ab	222 a	0 a	4 b	727 a
Carbofuran	22.9 g/100 m (7.5 kg/ha)	7,427 a	78 a	80 a	34 a	6 b	147 a	102 ab	2 a	166 a	930 a	555 a	0 a	9 ab	1,318 a
FMC 67825‡	6.4 ml/100 m (3.7 kg/ha)	7,420 a	77 a	80 a	38 a	0 b	140 a	40 b	21 a	193 a	526 ab	312 a	2 a	16 ab	814 a
Carbofuran	11.4 g/100 m (3.7 kg/ha)	7,395 a	80 a	80 a	59 a	11 b	202 a	114 ab	16 a	150 a	276 ab	398 a	0 a	10 ab	882 a
FMC 67825	8.5 g/100 m (2.8 kg/ha)	7,099 a	80 a	77 a	32 a	6 b	17 a	30 b	88 a	130 a	275 ab	371 a	1 a	38 a	673 a
FMC 67825‡	11.4 g/100 m (3.7 kg/ha)	6,885 a	73 a	75 a	18 a	0 b	78 a	46 b	18 a	71 a	789 ab	670 a	1 a	23 a	1,194 a
FMC 67825	11.4 g/100 m (3.7 kg/ha)	6,658 a	79 a	79 a	39 a	3 b	101 a	34 b	10 a	158 a	237 ab	376 a	7 a	6 b	1,036 a
FMC 67825	6.4 ml/100 m (3.7 kg/ha)	6,633 a	75 a	75 a	18 a	5 b	142 a	37 b	10 a	134 a	477 ab	336 a	10 a	25 ab	1,552 a
FMC 67825	4.8 ml/100 m (2.8 kg/ha)	5,959 a	78 a	81 a	26 a	3 b	56 a	39 b	30 a	90 a	289 ab	214 a	0 a	18 ab	1,036 a
Control	Untreated	1,587 b	14 b	12 b	30 a	77 a	144 a	165 a	6 a	236 a	133 b	276 a	0 a	6 b	1,870 a

Means with the same letter are not significantly different according to Duncan's new multiple-range test ($P = 0.5$).
† Rates were calculated based on a 102-cm row spacing.
‡ Plots covered with 1-mil plastic tarp immediately after planting to prevent wetting from irrigation and removed the following morning.

TABLE 2. Corn yield, plants and ears per treatment at harvest and average number of nematodes per 250 cm^3 soil at Pm and Pf and lesion nematodes per g roots at Pf as affected by treatment of nematicides in the north field.

					Soil								Roots
					Paratrichodorus		*Meloidogyne*		*Pratylenchus*		*Criconemella*		*Pratylenchus*
Treatments	Rate of active ingredient/18-cm band (broadcast rate)†	Yield kg/ha	Plants	Ears	71 days	139 days	71 days	139 days	71 days	139 days	71 days	139 days	159 days
FMC 67825	8.5 g/100 m (2.8 kg/ha)	7,823 a	81 a	82 a	30 ab	7 b	14 a	114 a	32 ab	176 ab	35 a	76 a	726 a
Carbofuran	22.9 g/100 m (7.5 kg/ha)	7,728 ab	79 a	81 a	104 a	14 ab	10 a	122 a	18 ab	148 ab	50 a	26 a	823 a
FMC 67825	4.8 ml/100 m (2.8 kg/ha)	7,690 ab	80 a	79 ab	36 ab	14 ab	15 a	171 a	42 ab	240 a	34 a	23 a	740 a
Carbofuran	11.4 g/100 m (3.7 kg/ha)	7,527 ab	81 a	79 ab	53 ab	29 a	19 a	433 a	9 b	83 ab	92 a	43 a	529 a
FMC 67825	6.4 ml/100 m (3.7 kg/ha)	7,338 ab	78 a	77 ab	54 ab	15 ab	10 a	464 a	1 ab	166 ab	114 a	57 a	650 a
FMC 67825	6.4 ml/100 m (3.7 kg/ha)	7,134 ab	82 a	76 ab	42 ab	15 ab	14 a	226 a	40 ab	10 ab	59 a	51 a	986 a
Carbofuran	11.4 g/100 m (3.7 kg/ha)	7,073 ab	77 ab	76 ab	58 ab	15 ab	1 a	437 a	5 b	50 b	37 a	67 a	484 a
FMC 67825‡	11.4 g/100 m (3.7 kg/ha)	7,067 ab	76 ab	74 ab	27 b	10 b	5 a	235 a	20 ab	113 ab	130 a	66 a	430 a
Control	Untreated	6,513 bc	69 bc	70 b	105 a	13 ab	38 a	325 a	63 a	169 ab	42 a	20 a	880 a
FMC 67825	11.4 g/100 m (3.7 kg/ha)	5,618 c	65 c	60 d	26 b	6 b	30 a	256 a	20 ab	47 b	105 a	49 a	1,721 a

Means with the same letter are not significantly different according to Duncan's new multiple-range test ($P = 0.5$).

† Rates were calculated based on a 102-cm row spacing.

‡ Plots covered with 1-mil plastic tarp immediately after planting to prevent wetting from irrigation and removed the following morning.

numbers of lesion nematodes per g of roots ($r = -0.28$) and root-knot nematodes per 250 cm^3 soil ($r = -0.29$) at harvest. Numbers of stalks also were inversely correlated ($P = 0.05$) to numbers of lesion nematodes per g roots ($r = -0.31$) at harvest.

In prior tests FMC 67825 caused a phytotoxic response to corn seedlings (unpubl.). It was hypothesized that irrigation water applied immediately after planting may have moved the chemical into contact with the seed. Although no visible symptoms of phytotoxicity were noted in these experiments, one treatment (FMC 67825, 11.4 g a.i./100 m, no plastic covering) in the north field had a lower yield, plant stand, and ears per plot ($P = 0.05$) than occurred in the parallel treatment covered with plastic (Table 2). We do not consider our results conclusive on this point because no significant differences were found between yields from other corresponding treatments covered with plastic vs. uncovered plots (Tables 1, 2).

The differences in the number of plants, ears, and yields in the control plots between the south and north fields were attributed mainly to the presence of sting nematode in the south field. Because stubby-root nematode also occurred in the south field and remained relatively high in numbers in the untreated plots, it was impossible to sort out the damage attributed only to sting nematode. Both nematodes caused greatly abbreviated root systems in young seedlings growing in border rows and untreated plots. The plant stands in the untreated plots were reduced because most severely affected plants died. There was an average stand reduction of 82% in untreated plots vs. treated plots. Nematode populations in the north field (no sting nematode) did not cause comparable seedling damage. Although the north field contained relatively heavy infestation of stubby-root, lesion, root-knot, and ring nematodes, only one treatment (FMC 67825, 8.5 g a.i./100 m) resulted in a yield that was significantly higher than the control.

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