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Nematicides and Nonconventional Soil Amendments in the Management of Root-Knot Nematode on Cotton[1]

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Abstract: Granular and liquid commercial humates, with micronutrients, and a microbial fermentation product were compared in several combinations with nematicides for their effects on cotton lint yield and root-knot nematode suppression. Fumigant nematicides effectively reduced cotton root galling caused by root-knot nematodes, and cotton lint yields increased. Organophosphates and carbamates were not effective. Occasionally, cotton lint yields were increased or maintained with combination treatments of humates, micronutrients, and a microbial fermentation product, but galling of cotton roots by root-knot nematodes was usually not reduced by these treatments.

Key words: Meloidogyne incognita, humates, micronutrients, microbial fermentation product, *Gossypium hirsutum,* nematicides.

Explanations for the possible mechanisms involved in the partial control of nematodes using soil amendments fall into two main categories (6,7). One, suggested by Thorne (9), is that the products of decomposing organic amendments are directly toxic to some nematodes. Another, suggested by Linford et al. (4), which is much quoted but not clearly demonstrated, is that microbivorous nematodes reproduce on bacteria and the decomposition products of organic amendments; the parasites and predators then increase to suppress plant parasitic nematodes as well as microbivorous ones. Organic amendments have been investigated extensively as contributing to the biological control of plant parasitic nematodes with varying levels of success. Many biological agents suppress plant parasitic nematodes, but not one is recommended or in general use for nematode control on crop plants (5–8). Quarantines are imposed to restrict nematode movement, but one of the reasons given for failure to obtain widespread biological control of plant parasitic nematodes is the difficulty in establishing their antagonists (predators, parasites, etc.) in the same soils; i.e., the ecosystem is buffered against change and resists the interposition of new organisms (5,10).

In a recent report on organic farming, a USDA study team noted that about 20% of all farmers used nontraditional soil and plant additives (marketed as soil humates, activators, conditioners, microbial fertilizers, inoculants, and plant growth stimulators) in their farming operations. The same report also observed that nematodes and plant pathogens did not offer any serious threat in the organically managed systems (11). These observations indicated a need to study the influence of such soil and plant additives on plant–nematode interactions. The objective of this research was to assess the value of additives for management of root-knot nematodes on cotton. The criteria for their usefulness were increase in cotton lint yield and reduction of galling by root-knot nematodes.

MATERIALS AND METHODS

Experiment 1: The experiment was conducted on a field of Wasco sandy loam (ca. 75% sand, 17% silt, and 7% clay), naturally infested with *Meloidogyne incognita* (Kofoid & White, Chitwood). The experimental design was a randomized complete block with 10 treatments and eight replications. Plots were four rows wide on 1-m centers and 23 m long. All treatments were applied in the centers of the row by tractor-mounted chisels before pre-irrigation. The fumigant, 1,3-dichloropropene (1,3-D) was applied at a depth of 56 cm; the granular compounds aldicarb, ethoprop, isazophos, and phenamiphos, and the bactericide nytrapyrin at 20 cm deep. A microbial fer-

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mentation product (MFP) containing six aerobic bacteria and fungi and three anaerobic bacteria with various vitamins, enzymes, and micronutrients was applied in split application, 60% at a depth of 15 cm and 40% sprayed on the soil surface and mixed into the soil with a tractor-mounted rotary cultivator. Acala SJ-2 cotton (*Gossypium hirsutum* L.) was planted 3 weeks after treatment. Irrigations were timed to induce flowering, maintain plant growth, and produce the best possible yields in the fumigated plots. Cotton was machine picked once from the center two rows of each plot. After harvest, the cotton plants were shredded with a rotary stalk cutter and the roots were dug with a tractor-drawn lifter. The roots of 30 plants from each plot were rated on a 0–4 scale, from no galls to completely galled, and weighted nematode ratings (WNRs) were calculated (2). Analyses of variance were performed on the raw data.

Experiment 2: This experiment was conducted the year following Experiment 1 in the same field and in essentially the same manner, except the rates of application of granular ethoprop were reduced and emulsifiable formulations of ethoprop and terbufos were substituted for isazophos and phenamiphos (Table 1).

Experiment 3: This experiment was conducted on a field, similar to that used for Experiments 1 and 2, which had received repeated applications of herbicides, nematicides, and fertilizers over many years. Cotton, barley (*Hordeum vulgare*), and okra (*Hibiscus esculentus*) were grown in rotation during the 9 years preceding this experiment. Soil organic matter was under 0.5%, increasing the chances for plant response from the humates which elicit their greatest plant growth response when applied to soils low in organic matter (3). The long period in host plants assured a root-knot nematode population >1 J2/ml soil, a level adequate for this test. Two granular humates, one with synthetic polymer, the other without; two formulations of micronutrients (Fe 1.0%, Zn 0.5%, Mn 0.5%) in liquid humate solutions with or without low amounts of N, P, K (urea 8%, P_2O_5 15%, K_2O 7%); and MFP were applied singly or in combinations. Humates were not characterized to determine the proportions of the various humate fractions. They were used as received from the suppliers and applied at the rates the suppliers recommended. Humates and the MFP were spread or sprayed on the surface of the beds with a tractor-mounted spreader or sprayer and mixed into the soil with a rotary cultivator before planting cotton. Micronutrients were sprayed on the cotton at squaring and again 3–4 weeks later. Plot size and other procedures were the same as in Experiments 1 and 2, but replicated six times.

Experiment 4: This experiment was conducted on a field artificially infested 8 years earlier using root-knot nematode infected tomato (*Lycopersicon esculentum*) seedlings produced in greenhouse ground beds. Okra, cotton, and tomatoes were grown in the 3 years immediately preceding this experiment. Before planting tomatoes, the total plot area received compost (2 tons/ha) followed by granular humate (45 kg/ha) applied by commercial applicators and incorporated by tractor-drawn disk in January immediately before bedding on 1-m centers. On 30 April MFP (11.2 kg/ha) was applied as in Experiment 1. The field was planted to a machine-picked tomato (UC-82) in the first week of May. The tomatoes were grown to maturity, the plant residue incorporated into the soil by a tractor-drawn disk, and the field was left fallow over the winter.

Excessive spring rain, which delayed land preparation and planting of cotton, precluded the need for pre-irrigation. Preplant treatments of ethylene dibromide (EDB) (11.4 liters/ha) and ethoprop (6.7 kg/ha) were not applied until mid April. Planting of cotton and the at-planting application of EDB (7.6 liters/ha) followed 6 days later. The first postplant applications of ethoprop and oxamyl were made 6 weeks after planting at the first irrigation in mid June, and continued at monthly intervals thereafter for 3 months. Nematicide was metered by a gravity flow applicator into the irrigation water to plots four rows wide and 45 m long; treatments were replicated four times. Other cultural and harvest procedures were the same as in Experiments 1, 2, and 3.

RESULTS

Experiment 1: Only 1,3-D at 94 liters/ha significantly reduced root-knot nematode

TABLE 1. Influence of various nematicides and biologicals on yield and root-knot nematode galling of cotton.*

	Formulation		Rate		Lint yield (kg/ha)		WNR†	
Treatment	(kg/liter)	(% a.i.)	(liters/ ha)	(kg a.i./ ha)	Experiment 1	Experiment 2	Experiment 1	Experiment 2
1,3-D	1.2	—	94.0	—	1,100 a	975 a	11 a	20 a
Aldicarb	—	15 G§	—	9.0	1,077 ab	725 b	61 b	66 b
Ethoprop	—	10 G	—	1.68		791 b		79 bc
	—	10 G	—	3.36		773 b		74 bc
	0.68 EC§	—	—	3.36		795 b		69 bc
	—	10 G	—	4.50	799 cd		64 bc	
	—	10 G	—	5.04		788 b		77 bc
	—	10 G	—	9.0	662 d		66 bcd	
	—	10 G	—	13.5	615 d		69 bcde	
Isazophos	—	10 G	—	9.0	977 abc		72 bcde	
MFP‡	—	—	—	11.2	1,006 ab	710 b	85 de	70 bc
Nytrapyrin	0.23 EC	—	2.5	—	895 bc	745 b	83 cde	79 bc
Phenamiphos	—	10 G	—	9.0	995 ab		68 bcde	
Terbufos	—	15 G	—	2.2		794 b		63 b
Nontreated	—	—	—	—	913 abc	701 b	86 e	83 c
	LSD 0.05				175	119	17	14

* Data are means of eight replications. Within a column, means followed by a letter in common are not significantly different according to Duncan's multiple-range test ($P < 0.05$).

† Weighted nematode rating: 0 = no galling, 100 = full galling.

‡ Microbial fermentation product.

§ G = granular, EC = emulsifiable concentrate.

populations as shown by cotton root galling (Table 1). Ethoprop at 4.5, 9.0, and 13.5 kg/ha was phytotoxic, significantly suppressing yields as compared to nontreated controls. Yields from plots receiving the other treatments were not significantly different from the controls. MFP appeared to enhance plant growth and vigor, but yield of lint was not increased significantly.

Experiment 2: 1,3-D at 94 liters/ha significantly reduced the nematode population based on root galling and was the only

TABLE 2. Influence of granular humates, macro and micronutrients and a microbial fermentation product (MFP) applied to soil on yield and root-knot nematode galling of cotton.*

	Rate			
Treatment	(liters/ ha)	(kg/ha)	Lint yield (kg/ha)	WNR†
Untreated			699 a	57 b
Micronutrients‡	0.66		765 ab	84 a
Macro + micronutrients§	1.06		884 bc	74 a
Micronutrients + MFP + granular humate	0.66+	11.2 ± 45	931 c	42 c
Macro + micronutrients + MFP + granular humate	1.06+	11.2 ± 45	976 c	37 c
Micronutrients + MFP + granular humate with synthetic polymer	0.66+	11.2 ± 45	924 c	39 c
Macro + micronutrients + MFP + granular humate with synthetic polymer	1.06+	11.2 ± 45	927 c	39 c
LSD 0.05			134	15
0.01			180	20

* Data are means of six replications. Within a column, means followed by a letter in common are not significantly different according to Duncan's multiple-range test ($P < 0.05$).

† Weighted nematode rating: 0 = no galling, 100 = full galling.

‡ Micronutrients (Fe 1.0%, Zn 0.5%, Mn 0.5%) foliar spray with adjuvant in liquid humate carrier.

§ Macro + micronutrients (urea 8.0%, P_2O_5 15.0%, K_2O 7.0%) foliar spray with (Fe 1.0%, Zn 0.5%, Mn 0.5%) in liquid humate carrier.

TABLE 3. Influence of nematicides, humates, and a microbial fermentation product (MFP) on yield and root-knot nematode galling of cotton.*

Treatment	Formulation (kg/liter)	Formulation (% a.i.)	Rate (liter/ha)	Rate (kg a.i./ha)	Lint yield (kg/ha)	WNR†
EDB	1.36		11.4		596 a	2 a
EDB	1.36		7.6		493 ab	9 a
Ethoprop	0.68 EC			6.7	360 bc	41 b
Ethoprop	0.68 EC			3.3‡	184 c	89 c
Oxamyl	0.23 EC			3.3‡	238 c	78 c
Humates + MFP		80		45 ± 11.2	245 c	89 c
Untreated					243 c	91 c
LSD 0.05					183	16

* Data are means of four replications. Within a column, means followed by a letter in common are not significantly different according to Duncan's multiple-range test ($P < 0.05$).

† Weighted nematode rating: 0 = no galling, 100 = full galling.

‡ Applied monthly for 3 months at the rate of 1.1 kg/ha.

treatment significantly increasing lint yield (Table 1). No ethoprop or terbufos treatment improved lint yield or reduced nematode populations significantly. The lower rates of ethoprop used in Experiment 2 as compared to Experiment 1 resulted in much less phytotoxicity. The yields from plots treated with aldicarb and nytropyrin were not improved, nor were nematode numbers decreased in the nytrapyrin plots. WNR in the aldicarb plots was significantly lower than in the nontreated plots. MFP failed to significantly increase lint yield or decrease cotton root galling.

Experiment 3: Compared with results from nontreated plots, yields were significantly higher and WNRs significantly lower from plots receiving combination treatments containing low rates of foliar micro or macro + micronutrients in a liquid humate carrier, MFP, and granular humates (Table 2). Yields from plots treated only with micro or macro + micronutrients trended higher, but only those from plots treated with macro + micronutrients were significantly higher than the nontreated. Plants from these same plots had more extensive root galling than those from the nontreated plots or plots treated with combinations containing granular humate and MFP.

Experiment 4: Only the two EDB treatments resulted in lint yields significantly higher than those from nontreated plots, and root galling was significantly lower in these two treatments (Table 3). Ethoprop applied at 6.7 kg/ha significantly lowered root galling, but yields were not increased significantly. Plots treated with humate + MFP and the nontreated plots had similar WNRs and yields.

DISCUSSION

Not all of these experiments gave evidence that MFP directly suppressed root-knot nematode on cotton or stimulated plant growth. Nematode populations were lowered most significantly by fumigant nematicides, as shown by root galling. The organophosphate and carbamate nematicides were much less effective than the fumigants. The bactericide, nytrapyrin, appeared to be phytotoxic in Experiment 1, which may account for the lack of yield improvement, but no phytotoxicity appeared in Experiment 2, nor were yields improved or WNRs lowered. Organic matter, a substrate for bacteria, was low in these plots and may partially account for the inconsistent yields of the plants treated with nytrapyrin and MFP in Experiments 1 and 2.

In Experiment 3, decreased galling by root-knot nematodes and concomitant lint yield increases occurred when granular and liquid humates were applied in combination with low amounts of macro and micronutrients and MFP. These results support previous reports that under some conditions, plant growth may be stimulated (3) and nematode survival and reproduction inhibited (1) by certain fractions of organic amendments applied to soil. Macro and micronutrients used alone increased root galling as well as improved yields when compared to the nontreated control, indicating that either the humates or MFP, or both, were possibly responsible for the lower WNRs. The reduction in galling resulting from these combination treatments, while significant, was not great. However, if ways can be devised to predict when and where there may be a need for these forms of organic amendments (3), they may help maintain fertility and yields and possibly even reduce nematode populations in long-term cropping systems.

As in these experiments, the objectives of applying MFPs to soil usually will be to enhance plant (crop) growth or yield and/or to manage pests. To achieve the objectives, careful planning, similar to that used in establishing cropping sequences, will need to prevail as MFPs come into use. The essential conditions required to increase or decrease each organism in proper order will need to be known and applied if the MFPs are to be usefully manipulated as plant growth stimulators, or as stimulators of nematode parasites and predators, or if the antagonists of nematodes or other organisms applied to soils will function as intended.

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