Criconemoides and *Paratrichodorus* were reduced at the 4.5 kg/ha application rate (Fig. 4 and 7).

Isazophos appeared to be singularly effective against *Belonolaimus* in test 2. The material was effective in lowering populations at the lowest concentration 2 and 3 months after application but attained its maximum effectiveness 6 months after application (Fig. 3). Its efficacy was not enhanced when it was applied with Maxicrop in test 1 (Fig. 2) or metalaxyl (test 2). It was the only treatment (2.2 kg/ha) that significantly increased root tensile strength as compared to control (Fig. 14).

Ethoprop usage in test 2 (Fig. 8) controlled *Hoplolaimus,* but its effect on root tensile strength was less than desirable (Fig. 14).

Inspection of the data presented graphically in the foregoing 2 tests points to the superiority of phenamiphos over the other materials used. Moderating considerations are that the results were based on only one test in which it was used and that the acute oral LD_{50} of phenamiphos indicate that it is a highly toxic material.

Studies such as this continue to point out the extreme desirability of a turfgrass nematode management program to use a variety of materials and practices to reduce symptoms and enhance turf growth—an integrated control program.

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APPLICATION OF AVERMECTIN AND CYROMAZINE VIA DRIP IRRIGATION AND FENAMIPHOS BY SOIL INCORPORATION FOR CONTROL OF INSECT AND NEMATODE PESTS IN CHRYSANTHEMUMS[1]

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Additional index words. Twospotted spider mite, *Liriomyza trifolii,* leafminer, flower thrips, root knot nematode, sting nematode, lance nematode, stubby root nematode.

Abstract. **The systemic granular nematicide, fenamiphos (Nemacur 15G), was incorporated into the soil (fall) and the insecticides cyromazine (fall) and avermectin (spring) were delivered via trickle irrigation to pompon chrysanthemums** (*Chrysanthemum* x *morifolium* **Ramat.). Cyromazine applied via trickle irrigation reduced the portion of leafmines that developed to the large stage and reduced densities of root knot nematodes** (*Meloidogyne incognita* **Kofoid and White) but did not affect the total numbers of leafmines or densities of twospotted spider mites** (*Tetranychus urticae* **Koch). Avermectin applied by trickle irrigation did not provide any significant reductions in twospotted spider mite, flower thrips, leafminer or plant parasitic nematode densities. Fenamiphos treatment resulted in reduced root knot and lance nematode** [*Hoplolaimus galeatus* **(Cobb) Filipjev and Schuurmans Stekhoven] presence and in increased spider mite densities. Cyromazine and avermectin applied by trickle irrigation did not provide acceptable control of nematode or arthropod pests. Preplant soil fumigation increased flower yield (stem weight); cyromazine, avermectin or fenamiphos did not affect yield.**

[1]Florida Agricultural Experiment Stations Journal Series No. 6152. Trade names are included for the benefit of the reader and do not imply any endorsement or recommendation by the authors.

Drip irrigation systems, designed to provide frequent, low volume irrigation to crops, conserve energy and labor in addition to conserving water. In recent years the systems also have been evaluated as vehicles for nutrient (5) and pesticide applications (2, 3, 4). A drip system is particularly advantageous for delivering appropriate pesticides for various reasons: 1) hazards to workers in treated plantings are reduced by delivering the chemical in a closed system that eliminates drift from sprays and eliminates chemical deposits on plant surfaces; 2) the chemicals do not come into direct contact with beneficial organisms (parasites and predators of the plant pests) on the above-ground environment; and 3) the system becomes more cost efficient by using it for as many operations as possible.

Pesticides delivered to the plant by trickle irrigation concentrate their effectiveness in the limited wetted area near the water emitters of the trickle tube where the crop roots develop. In this restricted zone of maximum root growth, nematodes and microbial pathogens develop. Injection of pesticides to this area places the chemical in the zone of greatest edaphic pest activity and in the zone from which roots absorb systemic materials for transport to above-ground plant parts.

Evaluation of nematicides that were found also to have insecticidal capability (2) suggested the need for evaluating systemic pesticides used to control foliar pests in a crop management program. This led to publication of research on arthropod control on chrysanthemums (4) using candidate insecticides/nematicides delivered by drip irrigation. The success of newer insecticides, such as cyromazine (Trigard) and avermectin (Avid), as foliar sprays for control of arthropods (8) stimulated the 2 experiments on pesticide injection via trickle irrigation systems discussed in this paper.

Materials and Methods

Both experiments were performed in a similar manner in 1983. The experimental site was a chrysanthemum range covered with saran shade cloth producing 25% shade on EauGallie fine sand (sandy, siliceous, hyperthermic Aeric haplaquod). Eight beds 22.7 m long, 0.9 m wide and 15 cm high were formed on 1.8-m centers. Slow release fertilizers (Osmocote), 14-14-14 and 19-6-12 were applied at 1344 and 672 kg/ha respectively, incorporated to a depth of 5 cm. Each bed was fitted with 3 lengths of Chapin Driphose tubing (emission ports on 30-cm centers) spaced equidistant (30 cm) apart in the bed width and buried 5 cm below the soil surface. Appropriate manifolds and submains were used to connect four 5.4-m, single-bed plots to a single water line. One of the 4 plots designated to receive the same treatment appeared in each of the 4 replications of fumigated and nonfumigated soil. The system was arranged for automated irrigation. Injections of insecticides were made with peristaltic pumps using silicone delivery tubes to transfer the chemical from a reservoir to the polyethylene irrigation mains.

The experimental design was a 2 x 4 factorial with treatment combinations replicated 4 times. Factor A was the absence of or use of chemical soil fumigation. In the spring experiment, the fumigant was 67% methyl bromide and 33% chloropicrin applied in a mixture at the rate of 392 kg/ha. In the fall experiment, the fumigant was 99.5% methyl bromide and 0.5% chloropicrin applied in a mixture at the rate of 336 kg/ha. Fumigants were injected 15 cm deep into the soil with 3 chisels spaced 20 cm apart. Black (spring) or white (fall), 1.25-mil thick, polyethylene film was sealed over all beds immediately after fumigants were applied.

Factor B was various uses of other pesticides. In the spring experiment, factor B treatments were avermectin 0.15 SL applied at 0.146, 0.291, or 0.584 kg a.i./ha delivered in 13 equal weekly doses beginning March 4, and an untreated check. In the fall experiment, treatments were technical cyromazine injected once weekly for 14 weeks at the rate of 0.14 kg a.i./ha following a single treatment at planting with twice that rate. Other factor B treatments in the fall were cyromazine 75WP sprayed on plant foliage at the rate of 0.14 kg a.i./ha each week in 2300 liters of water per ha for 14 weeks, fenamiphos (Nemacur 15G) incorporated to a 10-cm depth in the soil at 7.2 kg a.i./ha at the time fumigants were applied to plots so treated, and an untreated check.

Rooted chrysanthemum cuttings were planted through the mulch in 6 rows spaced on 15 cm squares 2 weeks after soil fumigation. In the spring, each plot was composed of subplots of 'Polaris', 'Golden Polaris', 'Manatee Yellow Iceberg' and 'Florida Marble' chrysanthemums. In the fall, only 'Manatee Iceberg' chrysanthemums were planted. Long day conditions were provided the crops for 1 month after planting and fungicides were routinely scheduled throughout the growing seasons.

Important arthropod pests infesting plants during the experiments were monitored. Samples of 10 leaves per plot were taken from the middle 1/3 strauum of 'Manatee Yellow Iceberg' subplots May 6 and 13 and on June 6 during the spring to determine densities of spider mite populations. Similar samples were taken from plots on November 21 and on December 12 during the fall experiment. Mites were brushed from leaves onto a rotating disc and mites from 1/10 the disc area were counted according to the method described by Price et al. (6).

On June 6 (spring experiment), samples of 10 mature flowers per plot were taken from 'Polaris' subplots. Thrips were extracted from the flowers by a process described for extracting mites (7) and counted.

Densities of leafmines in plots were determined in the spring by counting and summing all mines present on 3 stems on the outside row of each of the subplots on June 3. At the time of harvest in the fall, the average numbers of mines per stem and the percent of those mines that were large (about the size formed by third instars) were determined by counting all small, medium and large mines from the 12 stems of 2 rows across a bed in each plot.

Soilborne nematode populations were assayed by the method described by Christie and Perry (1) from 100-ml samples of soil taken from each plot at harvests. Also, at the conclusion of both seasons, chrysanthemum stems were counted and weighed together to determine the average weight per stem from each plot.

Results and Discussion

No significant interactions occurred between treatment factors A (fumigation) and B (other pesticides). Therefore effects of the factors are presented independently.

Spring experiment. Populations of the twospotted spider mite, a flower thrips (*Frankliniella cephalica* Crawford) and a leafminer [*Liriomyza trifolii* (Burgess)] reached densities that would have required pesticidal treatments had the crops been grown for trade. Avermectin provided to the plants by trickle irrigation in the spring did not provide any significant reductions in these pests of chrysanthemum leaves or flowers (Table 1).

Planting the crop in fumigated soil that season resulted in lower numbers of twospotted spider mites on leaves at the time of the May 6 observation but not at the times of the later observations. The use of the soil fumigant did not affect the presence of nymphal thrips, numbers of leafmines nor the portion of the leafmines that reached large size.

Table 1. Number of twospotted spider mites, nymphal thrips, leafmines, and nematodes and weights of stems recorded from chrysanthemums grown in fumigated or nonfumigated soil (Factor A) and treated with avermectin delivered by trickle irrigation (Factor B). Spring 1983.

Treatment	Motile mites/leaf May 6	Motile mites/leaf May 13	Motile mites/leaf June 6	Thrips nymphs/10 flowers	Mines/stem Total	Mines/stem % large mines	Grams/stem	Nematodes/100 ml soil Stubby root	Nematodes/100 ml soil Others[z]
Factor A									
Nonfumigated	13.7 a[y]	29.8 NS	2.6 NS	162 NS	177 NS	23.6 NS	145 b	80 NS	160 a
Fumigated	7.0 b	23.7	2.1	167	160	21.7	194 a	71	4 b
Factor B									
Control	8.3 NS	31.9 NS	2.9 NS	136 NS	156 NS	22.6 NS	180 NS	67 NS	43 b
Avermectin 1.2 ml/wk	10.5	31.4	1.0	114	176	24.3	186	105	77 ab
Avermectin 2.4 ml/wk	9.4	17.0	2.5	195	175	24.1	152	70	111 a
Avermectin 4.8 ml/wk	13.3	26.8	3.0	214	166	19.4	160	59	97 a

[z]Values indicate sting, larval, root-knot, and lance nematodes.
[y]Mean separation within column and factor by Duncan's multiple range test, 5% level.

Table 2. Number of twospotted spider mites, leafmines, and nematodes and the weights of stems recorded from chrysanthemums grown in fumigated or nonfumigated soil (Factor A) and treated with cyromazine delivered by trickle irrigation or treated with fenamiphos granules incorporated into the soil (Factor B). Fall 1983.

Treatment	No. mites		Mines at harvest		Nematodes/100 ml soil				
	Nov. 21	Dec. 12	No./stem	% large	Sting	Root-knot	Lance	Stubby root	Grams/stem
Factor A									
Nonfumigated	48 NS[z]	116 NS	19.9 NS	39.3 NS	17 a	12 NS	0 a	7 b	216 b
Fumigated	50	101	20.6	40.8	147 b	6	11 b	4 a	240 a
Factor B									
Control	67 NS	101 a	23.3 b	55.8 c	94 NS	18 B	12 b	6 NS	222 NS
Cyromazine injected	34	85 a	21.6 ab	43.8 b	105	3 a	4 ab	6	226
Cyromazine sprayed	55	114 ab	15.4 a	4.5 a	86	12 ab	3 b	6	231
Fenamiphos	134	134 b	21.2 ab	56.2 c	45	3 a	3 b	5	234

[z]Mean separation within column and factor by Duncan's multiple range test, 5% level.

Population densities of the various nematode species were low during the spring experiment. Therefore data are presented for the most abundant species, the stubby root nematode [*Paratrichodorus* (N.) *christiei* (Allen) Siddiqi)], and for the sums of the other pest nematodes recorded. Those included the sting nematode (*Belonolaimus longicaudatus* Rau, the root knot nematode, the lance nematode and *Tylenchorhynchus*.

Fumigation treatment that season reduced nematode population densities and increased chrysanthemum stem weights, but avermectin treatments had no effect on stem weights. However, the sum of all nematodes (excluding the stubby root nematode) was higher in plots treated with the 2 higher concentrations of avermectin than in plots that were untreated. Avermectin treatments did not affect densities of stubby root nematodes.

Fall experiment. The twospotted spider mite and the leafminer were economically damaging pests in the fall experiment (Table 2). Leaf samples taken on December 12 revealed there was a significant increase in spider mite densities in plots treated with fenamiphos granules as compared to densities in nontreated plots and in plots that cyromazine was applied via trickle irrigation. Cyromazine applied to plants as a spray significantly reduced numbers of leafmines that were initiated, but cyromazine applied via trickle irrigation did not. Both methods of cyromazine application reduced the portion of mines that developed to the large size, however the portion developing on plants treated with cyromazine spray was much smaller than the portion developing on plants treated with cyromazine provided via trickle irrigation. Cyromazine applications did not affect densities of the twospotted spider mite when compared to densities in the untreated check. Spider mite populations, numbers of leafmines and the portion of large leafmines were not affected by the use of the soil fumigant in the fall experiment.

During the fall experiment, the same nematodes were present as were during the spring experiment, but their numbers were greater in the fall (Table 2). Fenamiphos granules reduced populations of root knot and lance nematodes but not the sting or stubby root nematodes. Root knot nematodes were reduced by cyromazine delivered by trickle irrigation but were not reduced by spray applications of the same compound. Spray applications of cyromazine reduced populations of the lance nematode while cyromazine delivered by trickle irrigation provided no significant reduction. Populations of the stubby root nematode were not affected by either the cyromazine nor the fenamiphos treatments.

Preplant fumigation with methyl bromide/chloropicrin reduced sting and lance nematode densities in the fall but did not provide a significant reduction on root knot nematode populations that season. It did result in an increase in stubby root nematode populations.

The average weights of chrysanthemum stems in the fall were unaffected by cyromazine applications or fenamiphos treatment (Table 2). However, stem weights were higher when methyl bromide/chloropicrin was used to fumigate the soil than when the soil was not fumigated.

Conclusions

The overall level of nematode and arthropod pest population reductions in these experiments by trickle irrigation delivery of cyromazine and avermectin were insufficient to warrant commercial use. Although the preplant soil fumigant increased yield, cyromazine, avermectin or fenamiphos did not affect yield. These data, along with those previously reported (2, 4) indicate that in order for a trickle irrigation delivery system to become an important component of crop management, pesticides delivered must be carefully selected. Further evaluations of systemic nematicides, insecticides and miticides should be made to achieve the potential of the trickle irrigation system as a vehicle for successful pest management.

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