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COMPARATIVE NEMATICIDAL EFFICACIES OF SEVERAL COMMERCIAL PRODUCTS ON BERMUDAGRASS[1]

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Abstract. **Cyromazine, ethoprop, isazophos, isofenphos, Maxicrop seaweed extract, metalaxyl, and phenamiphos were applied either singly or in combination in 2 tests to 'Ormond' Bermudagrass (Cynodon dactylon) turf parasitized by lance, (Hoplolaimus galeatus), ring (Criconemoides epp.) spiral (Helicotylenchus dihystera), sting (Belonolaimus longicaudatus), and stubby-root (Paratrichodorus christiei) nematodes. Nematode counts of each of the above nematode genera were obtained before and at 1, 2, 3, and 6 months after application of treatments. Grass clipping weights were measured at monthly intervals and root tensile strength readings were taken at the conclusion of the tests. Treatment with phenamiphos resulted in the best nematode control; isazophos and isofenphos, an insecticide, also were effective nematicides. Maxicrop, a plant growth promoter, improved turf growth.**

The control of plant parasitic nematodes continues to be a subject of much importance, primarily in the management of golf courses, sports areas, and home lawns. Restrictions placed on many of the materials previously used make evaluation of new substances for such use a continuing necessity (3, 4, 5). Primary emphasis in such tests is placed on the evaluation of materials, which are safer, used in smaller doses, and are more effective. Investigations have also been directed towards turfgrass resistance to nematodes (2, 6), treatment of turfgrass seed (7), and use of algal extracts (1, 4).

The research herein reported evaluated several chemical products, singly or in combination, and a kelp extract applied to nematode-infected golf turf. Effect on discrete nematode populations, grass growth, and root development were evaluated.

Materials and Methods

Two concurrent tests were performed on separate fairways of nematode-infected 'Ormond' Bermudagrass turf [*Cynodon dactylon* (L.) Pers.] at the University of Florida golf course. Test site No. 1 was parasitized mainly by sting nematodes (*Belonolaimus longicaudatus* Rau), 2 species of ring nematodes (*Criconemoides* spp.), spiral nematodes [*Helicotylenchus dihystera* (Cobb)], and stubby-root nematodes [*Paratrichodorus christiei* (Allen)]. Test site No. 2 was parasitized by sting, ring, and lance nematodes [*Hoplolaimus galeatus* (Cobb)]. Both test areas measured 36.6 x 12.8 m and were divided into 6.1 x 1.5 m (9.3 m^2) plots with 8 treatments randomized within each of 6 replicate blocks. Treatments for test 1 were applied at 1/3 the total dosage at 1-month intervals on May 25, June 22, and July 20, 1983 and for test 2 on June 9, July 6, and August 2. The treatments in test 1 were Maxicrop seaweed extract at 13.8, 9.2 and 4.6 liters/ ha; cyromazine (Trigard 75 W-D) at 6.7 kg (a.i.)/ha; isofenphos (Oftanol 5G) at 9 or 4.5 kg (a.i.)/ha; isazophos (Triumph 4E) at 1.1 kg (a.i.)/ha with Maxicrop applied at 4.6 liters/ha 2 weeks later; and untreated controls. On August 22, ethoprop mistakenly was applied by the grounds crew at the rate of 9 kg (a.i.)/ha to the entire test 1 area.

Treatments in test 2 were isazophos at 3.4 or 1.7 kg (a.i.)/ha; isazophos at 2.2 and 1.1 kg (a.i.)/ha combined with metalaxyl (Ridomil) at 1.1 kg (a.i.)/ha; metalaxyl at 1.1 kg (a.i.)/ha; phenamiphos (Nemacur 15G) at 16.8 kg (a.i.)/ha; ethoprop (Mocap 10G) at 22.4 kg (a.i.)/ha; and untreated controls.

All treatment areas were irrigated with approximately 1.3 cm of water the day prior to application of materials. Granular materials (isofenphos, phenamiphos, and ethoprop) were applied and washed into the soil with approximately 11.4 liters of water. After application of materials, the entire area was irrigated with approximately 0.6 cm of water.

Soil temperatures at a 6-cm depth on the first and last application dates were 26 and 28°C respectively for test 1 and 27°C on both application dates for test 2.

Six cores of soil and roots, 2 cm diameter and 15 cm long, were collected from each replicate plot before treatment and 1, 2, 3, and 6 months after treatment. The soil cores were combined and mixed thoroughly and 100-cm^3 aliquants were processed for nematodes by decantation and a standard sugar elutriation technique. The plant parasitic nematodes obtained were identified and counted; data were statistically evaluated by analysis of covariance.

Grass clippings from each replicate plot were obtained 1, 2, and 3 months after application of treatments. These were dried and weighed and the data were statistically evaluated.

Shortly after final data for the 6-month sampling were obtained, sod tensile strength readings were obtained from each plot. A manure fork with 8 curved tines was inserted 15 cm into the soil with the tines curving under the sod at an angle of 12° from the perpendicular. A scale was attached to the middle of the fork handle and a pulling force was applied at the opposite end of the scale (Fig. 1). The

Fig. 1. Manure fork with attached scale used for determining tensile strength of the sod.

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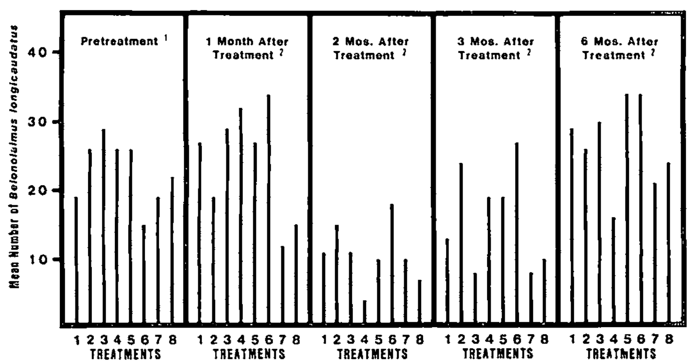
maximum force at which roots began to break was recorded. The mean of 5 readings per plot in 6 replicate blocks was recorded for each test.

Results

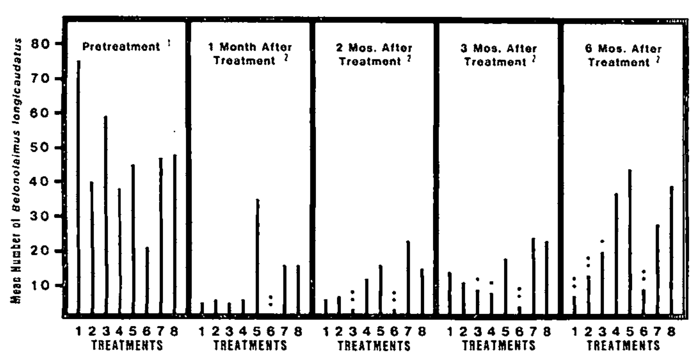
Belonolaimus longicaudatus. The 4 post-treatment soil samplings for test 1 (Fig. 2) revealed no significant reductions of sting nematode numbers by any of the test materials, as compared to controls. In test 2 (Fig. 3), phenamiphos (Treatment 6) reduced sting nematode populations significantly (P = 0.05) for each of the 4 sampling periods up to 6 months following treatment application. Isazophos at 2.2 kg/ha with metalaxyl at 1.1 kg/ha (Treatment 3) significantly reduced the sting nematode population (P = 0.05) 2 months after the last treatment application and continued to reduce populations as compared to controls (P = 0.10) for the duration of the 6-month data collecting period. Isazophos at 3.4 and 1.7 kg/ha (Treatments 1 and 2) significantly reduced the nematode population (P = 0.05) by the 6-month sampling.

Criconemoides spp. Isofenphos at 9 kg/ha (Treatment 5) controlled ring nematodes (P = 0.10), as compared to the controls 2 months after the last of the 3 treatment applications for test 1 (Fig. 4). After 6 months, both isofenphos treatments (No. 5 and 6) resulted in significant control



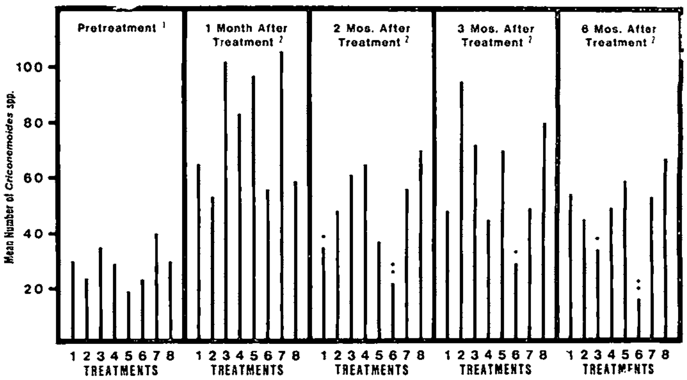
¹ Differences between means not statistically significant as determined by Duncan's multiple range test.
² Analysis of covariance

Fig. 2. Test 1: Average mean numbers of *Belonolaimus longicaudatus* per 100 cm³ of soil before and after treatment. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.



¹ Differences between means not statistically significant as determined by Duncan's multiple range test.
² Adjusted means (analysis of covariance)
* Only treatment means significantly lower than controls are indicated (* $P_{.10}$, ** $P_{.05}$)

Fig. 3. Test 2: Average mean numbers of *Belonolaimus longicaudatus* per 100 cm³ of soil before and after treatment. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.



¹ Differences between means not statistically significant as determined by Duncan's multiple range test.
² Analysis of covariance
* Only treatment means significantly lower than controls are indicated (* $P_{.10}$, ** $P_{.05}$)

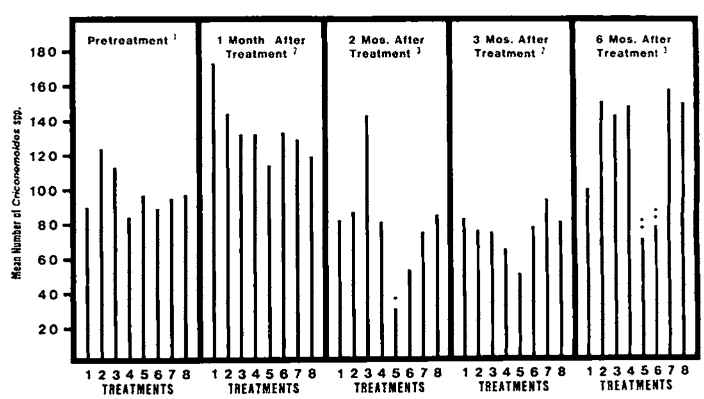
Fig. 4. Test 1: Average mean numbers of *Criconemoides* spp. per 100 cm³ of soil before and after treatment. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.

(P = 0.05) of ring nematodes. Phenamiphos (Treatment 6) sporadically controlled nematodes in test 2 (Fig. 5) at the second and 6-month sampling (P = 0.05) and at the third month sampling (P = 0.10). Nematode control (P = 0.10) was evident 2 months after treatment with isazophos at 3.4 kg/ha (Treatment 1) and 6 months after treatment with isazophos and metalaxyl combined at 2.2 and 1.1 kg/ha respectively (Treatment 3).

Helicotylenchus dihystera. Two months after application of treatments in test 1, cyromazine at 6.7 kg/ha (Treatment 4) and isofenphos at 9 kg/ha (Treatment 5) significantly reduced (P = 0.05) the number of spiral nematodes, as compared to controls (Fig. 6).

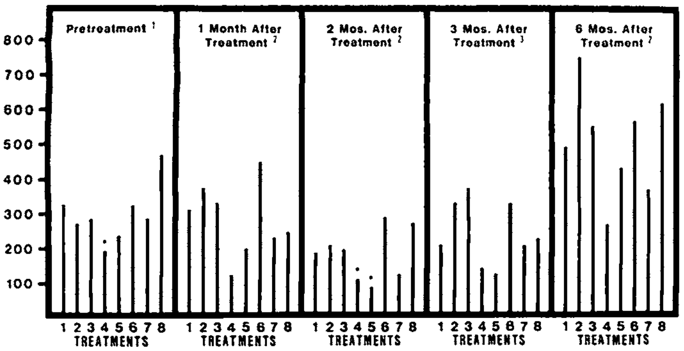
Paratrichodorus christiei. Two months after treatment applications in test 1, isofenphos at 4.5 kg/ha (Treatment 6) reduced the number of stubby-root nematodes as compared to the controls (P = 0.05) (Fig. 7). Six months after treatment, only Maxicrop at 4.6 liters/ha (Treatment 3), Maxicrop at 13.8 liters/ha (Treatment 1) and isofenfos at 4.5 kg/ha (Treatment 6) appeared to be effective in reducing populations of this species (P = 0.05, 0.10, and 0.10 respectively).

Hoplolaimus galeatus. Ethoprop at 22.4 kg/ha (Treatment 7, test 2) reduced lance nematode populations, as com-



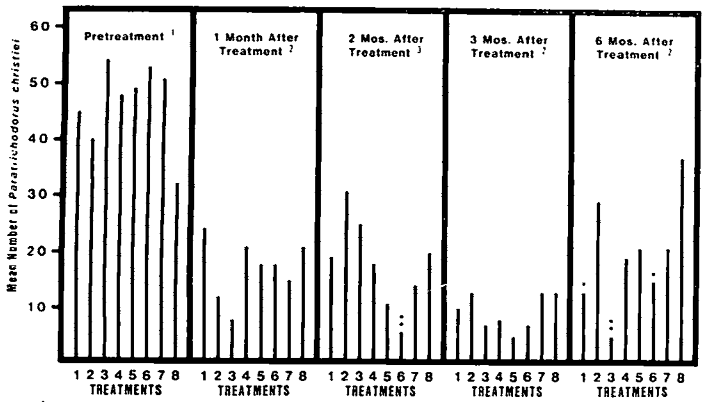
¹ Differences between means not statistically significant as determined by Duncan's multiple range test
² Unadjusted means (analysis of covariance)
³ Adjusted means (analysis of covariance)
* Only treatment means significantly lower than controls are indicated (* $P_{.10}$, ** $P_{.05}$)

Fig. 5. Test 2: Average mean numbers of *Criconemoides* spp. per 100 cm³ of soil before and after treatment. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.



[1] Treatment means significantly lower than the controls, as determined by Duncan's multiple range test, are indicated (•).
[2] Unadjusted means (analysis of covariance)
[3] Adjusted means (analysis of covariance)
• Treatment means significantly lower than the controls at $P_{.05}$

Fig. 6. Test 1: Average mean numbers of *Helicotylenchus dihystera* per 100 cm³ of soil before and after treatment. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.



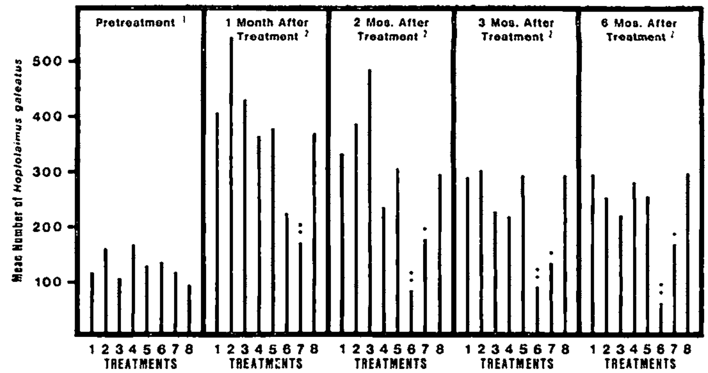
[1] Differences between means not statistically significant as determined by Duncan's multiple range test.
[2] Unadjusted means (analysis of covariance)
[3] Adjusted means (analysis of covariance)
• Only treatment means significantly lower than controls are indicated (• $P_{.10}$, •• $P_{.05}$)

Fig. 7. Test 1: Average mean numbers of *Paratrichodorus christiei* per 100 cm³ of soil before and after treatment. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.

pared to the controls, 1 month after application ($P = 0.05$) and continued to depress population growth ($P = 0.10$) over the following 5 months (Fig. 8). Two months after application and for the duration of the 6-month sampling period, phenamiphos at 16.8 kg/ha (Treatment 6) also resulted in significant reductions ($P = 0.05$) of the lance nematode populations, as compared to controls.

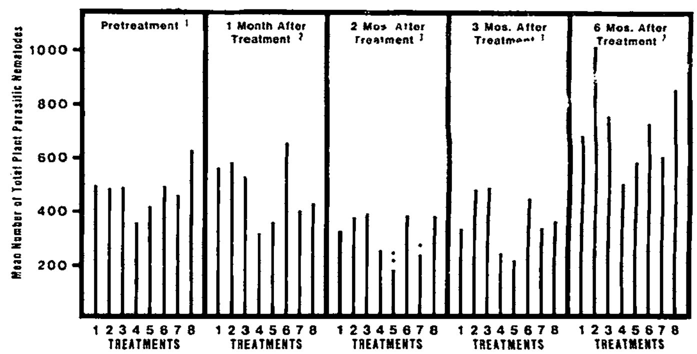
Total Plant Parasitic Nematodes. Isofenphos at 9 kg/ha (Treatment 5, test 1) and isazophos at 1.1 kg/ha with Maxicrop at 4.6 liters/ha (Treatment 7), applied 2 weeks later, reduced ($P = 0.05$ and 0.10 respectively) the total number of plant parasitic nematodes, as compared to the controls, 2 months after application of the test materials (Fig. 9). One month after treatments were applied to test 2 (Fig. 10), phenamiphos at 16.8 kg/ha (Treatment 6) reduced the plant-parasitic nematode population, as compared to the controls, throughout the 6-month sampling period.

Grass weight. Grass clipping weights in test 1 (Fig. 11) did not show any significant increase due to treatment, as compared to controls, with the sole exception of Maxicrop at 9.2 liters/ha (Treatment 2). The contemplated 6-month grass harvest of this test was cancelled due to extensive mole



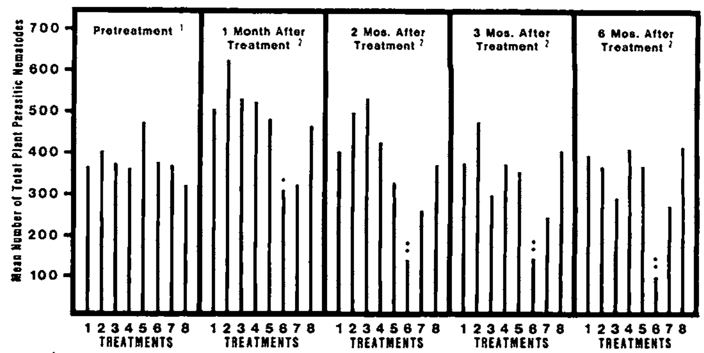
[1] Differences between means not statistically significant as determined by Duncan's multiple range test.
[2] Adjusted means (analysis of covariance)
• Only treatment means significantly lower than controls are indicated (• $P_{.10}$, •• $P_{.05}$)

Fig. 8. Test 2: Average mean numbers of *Hoplolaimus galeatus* per 100 cm³ of soil before and after treatment. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.



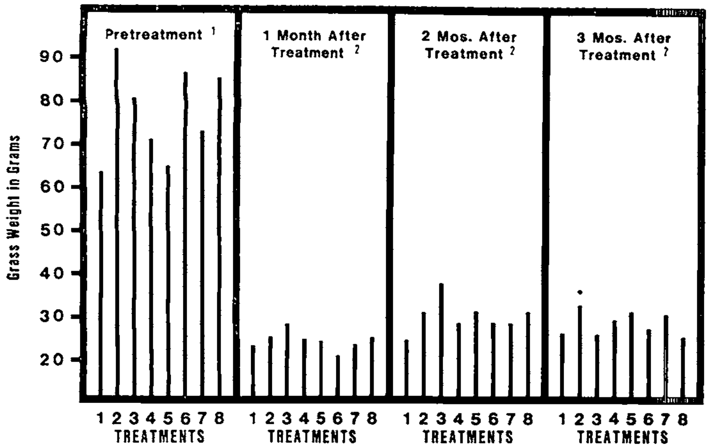
[1] Differences between means not statistically significant as determined by Duncan's multiple range test.
[2] Unadjusted means (analysis of covariance)
[3] Adjusted means (analysis of covariance)
• Only treatment means significantly lower than controls are indicated (• $P_{.10}$, •• $P_{.05}$)

Fig. 9. Test 1: Average mean numbers of total plant parasitic nematodes per 100 cm³ of soil before and after treatment. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.



[1] Differences between means not statistically significant as determined by Duncan's multiple range test.
[2] Adjusted means (analysis of covariance)
• Only treatment means significantly lower than controls are indicated (• $P_{.10}$, •• $P_{.05}$)

Fig. 10. Test 2: Average mean numbers of total plant parasitic nematodes per 100 cm³ of soil before and after treatment. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.



1 Differences between means not statistically significant as determined by Duncan's multiple range test.
2 Analysis of covariance * Treatment means significantly greater than controls ($P_{.10}$)

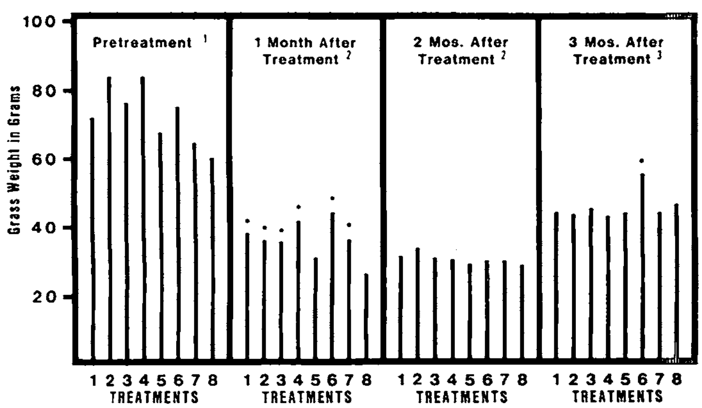
Fig. 11. Test 1: Average mean dry weights of grass following application of treatments. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop® @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.

cricket damage in parts of the experimental area. One month after application of materials in test 2 (Fig. 12), only metalaxyl at 1.1 kg/ha (Treatment 5) failed to show a significant (P = 0.05) increase in grass yield as compared to yields from the controls. Only treatment with phenamiphos at 16.8 kg/ha (Treatment 6) resulted in a significant increase in grass yield after 3 months.

Sod tensile strength. There were no significant differences in test 1 (Fig. 13) between sod tensile strengths in the control plots and plots receiving test materials; however roots in plots treated with Maxicrop at 9.2 liters/ha (Treatment 2) did have a greater resistance to breakage than the other treatments. There was an increase of root resistance to breakage as compared to the control (P = 0.10) in test 2 (Fig. 14) where isazophos/metalaxyl (Treatment 3) had been applied.

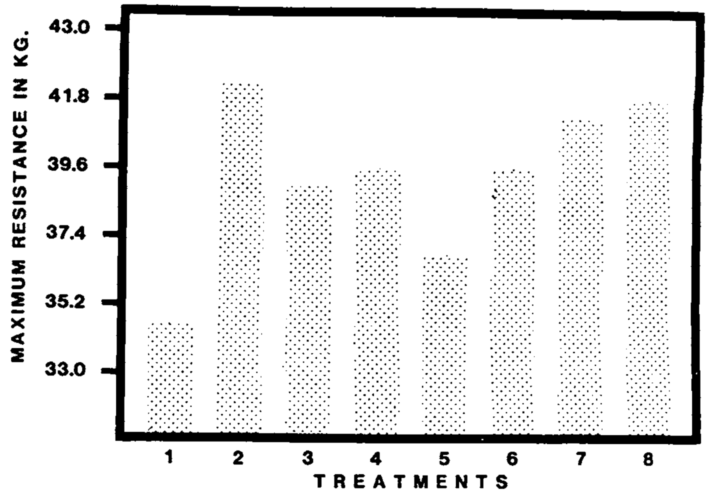
Discussion

Data from both tests indicate that phenamiphos, isofen-



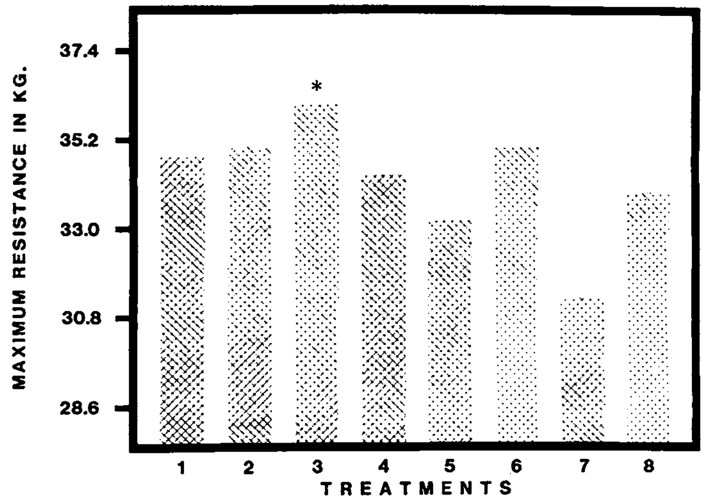
1 Differences between means not statistically significant as determined by Duncan's multiple range test.
2 Unadjusted means (analysis of covariance)
3 Adjusted means (analysis of covariance)
* Treatment means significantly greater than controls ($P_{.05}$)

Fig. 12. Test 2: Average mean dry weights of grass following application of treatments. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.



Differences between means not statistically significant as determined by Duncan's multiple range test.

Fig. 13. Test 1: Average mean sod tensile strength values obtained 6 months after application of treatments. Treatment code: 1. Maxicrop® seaweed extract @ 13.8 liters/ha; 2. Maxicrop @ 9.2 liters/ha; 3. Maxicrop® @ 4.6 liters/ha; 4. Cyromazine @ 6.7 kg(a.i.)/ha; 5. Isofenphos @ 9.0 kg(a.i.)/ha; 6. Isofenphos @ 4.5 kg(a.i.)/ha; 7. Isazophos @ 1.1 kg(a.i.)/ha + Maxicrop® @ 4.6 liters/ha; 8. Untreated control.



* Treatment means significantly greater than control ($P_{.10}$) as determined by Duncan's multiple range test

Fig. 14. Test 2: Average mean sod tensile strength values obtained 6 months after application of treatments. Treatment code: 1. Isazophos @ 3.4 kg(a.i.)/ha; 2. Isazophos @ 1.7 kg(a.i.)/ha; 3. Isazophos @ 2.2 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 4. Isazophos @ 1.1 kg(a.i.)/ha + metalaxyl @ 1.1 kg(a.i.)/ha; 5. Metalaxyl @ 1.1 kg(a.i.)/ha; 6. Phenamiphos @ 16.8 kg(a.i.)/ha; 7. Ethoprop @ 22.4 kg(a.i.)/ha; 8. Untreated control.

phos and isazophos were the best treatments for reducing nematode populations or enhancing turf growth.

Phenamiphos effectively lowered populations of *Hoplolaimus* and *Belonolaimus* during the entire 6-month observational period after application, as compared to populations from control plots (Fig. 3 & 8). *Criconemoides* populations were generally lower in treated plots than those in control plots from the second to the sixth month after treatment (Fig. 5). Phenamiphos was the only treatment to consistently and significantly lower populations of all plant-parasitic nematodes, as compared to control data in test 1 (Fig. 10). It and Maxicrop at 9.2 liters/ha were the only materials favorably affecting grass growth 3 months after treatment (Fig. 11 and 12). The results from plots treated with isofenphos proved interesting in that populations of

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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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.**

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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 aboveground 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.