Control of Cucumber Foliar Diseases, Fruit Rot, and Nematodes by Chemicals Applied Through Overhead Sprinkler Irrigation

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ABSTRACT

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Application of fungicides through irrigation water was compared with application by tractor-mounted boom or downdraft sprayers for control of foliar diseases on cucumber. Chlorothalonil applied through irrigation water and applied with tractor-mounted sprayers provided equal disease control in a resistant cultivar where gummy stem blight and target spot were the major diseases. In contrast, when an epidemic of downy mildew developed in a susceptible cultivar, chlorothalonil, mancozeb F, and mancozeb WP were more effective in lowering the infection rate and reducing disease severity when applied by ground sprayers than when applied through irrigation water. Control of root-knot nematodes with a nematicide (phenamiphos) reduced fruit rot and increased yield in plots sprayed with chlorothalonil, but foliar injury was so severe in unsprayed plots that nematode control was not beneficial.

The expansion of irrigation in Georgia was very rapid during the recent decade. Currently more than 340,000 ha are irrigated (12). Methods of vegetable production in the Georgia Coastal Plain have also changed considerably. Whereas many growers produced a variety of vegetables in small fields without irrigation or regular pest control in the past, almost all commercial vegetables are now grown in fields of 5–50 ha with overhead sprinkler irrigation and a planned pest control program. Thus, application of chemicals through irrigation water is possible for pest control.

Research on potatoes in Idaho (5) and on carrots and sugar beets in Michigan (6,8) indicated that fungicides applied through irrigation water are as satisfactory as those applied with ground sprayers or aircraft. Furthermore, damage caused by tractor wheels is eliminated (7,9).

Cucumbers are grown widely for processing and the fresh market in the Georgia Coastal Plain. The crop is susceptible to many foliar diseases and fruit rots, and most fields in Georgia are sprayed with fungicides to ensure high yields of marketable fruits (14). Common foliar diseases in Georgia include downy mildew caused by *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow, gummy stem blight caused by *Mycosphaerella melonis* (Pass.) Chiu & Walker, anthracnose caused by *Colletotrichum lagenarium* (Pass.) Ell. & Halst., target spot caused by *Corynespora cassiicola* (Berk. & Curt.) Wei, and *Cercospora* leaf spot. Fruit rots are caused by *Rhizoctonia solani* Kuehn, *Pythium* spp., and other fungi (14).

Cucumber is grown in monocropping and multicropping systems, but continuous cucumber production may increase the severity of some foliar diseases (11). Moreover, cucumber is very susceptible to the root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood), and an integrated pest management program is necessary for the production of a profitable yield of high quality cucumbers in the Georgia Coastal Plain (3). Nematicides have been applied successfully through overhead irrigation water on tomato (2) but not on cucumber.

This research was initiated to determine whether fungicides and a nematicide could be applied successfully through sprinkler irrigation water to control foliar diseases and nematodes on cucumber and could thus alleviate crop damage and soil compaction caused by driving ground equipment through the vines.

MATERIALS AND METHODS

Cucumber (*Cucumis sativus* L.) was grown for fresh market fruit under solid-set, overhead sprinkler irrigation on Lakeland sand (93.5% silt, 2.9% clay, and 3.6% sand) in two experiments in 1979. In the first experiment, cultivar Gemini 7, which is resistant to several foliar diseases, was planted on 20 March in soil not previously planted to cucumber. In the second test, Marketer, a cultivar that is susceptible to several foliar diseases, was planted on 2 August in different plots after a spring (April to June) crop of cucumber.

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Table 1. Effect of chlorothalonil applications on a 1979 spring crop of Gemini 7 cucumber

Treatment	Rate (kg/ha)	Foliar disease[x] June 8	No. of fruits rotted (%)	Marketable yield (kg/ha)
Chlorothalonil[y]				
I	2.33	3.2 b[z]	0	14,007 a
S	2.33	2.8 b	0.7	12,637 a
Control		6.0 a	4.9	8,037 b

[x]Rated by visual observations on a 1–10 scale: 1 = 0–10, 2 = 11–20, 3 = 21–30, 4 = 31–40, 5 = 41–50, 6 = 51–60, 7 = 61–70, 8 = 71–80, 9 = 81–90, and 10 = 91–100% of the foliage discolored or destroyed by gummy stem blight and target spot.

[y]I = fungicides siphoned into the irrigation water, S = applied with a Myers downdraft ground sprayer. Applications were 9 or 10 May, 22 May, and 29 May.

[z]Numbers in a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. Absence of letters indicates no significant differences.

A randomized complete block design with four replications was used in each test. Each plot was 12.2 × 12.2 m with 10 rows of cucumbers 0.9 m apart. Irrigation water was applied with two Rainbird model 25 PJ 9/64 sprinklers on risers 1.2 m high on opposite corners of each plot. This arrangement gave an approximate 6.85 × 6.85 m parallelogram in the center of each plot that was uniformly watered at 12 mm/ha/hr.

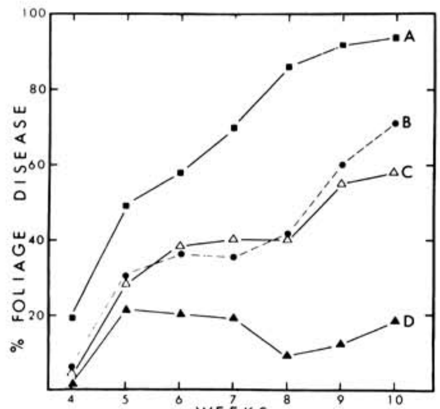

Fig. 1. Foliar disease severity in Marketer cucumber from 30 August to 12 October 1979, 4–10 wk after planting: **(A)** Control. **(B)** Captafol applied through irrigation water. Chlorothalonil applied **(C)** through irrigation water and **(D)** by a ground sprayer.

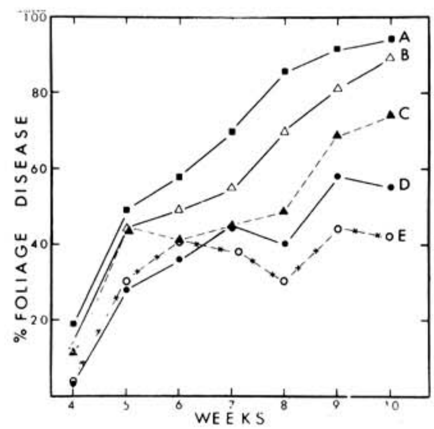

Fig. 2. Foliar disease severity in Marketer cucumber from 30 August to 12 October 1979, 4–10 weeks after planting: **(A)** Control. **(B)** Mancozeb F applied through irrigation water. Mancozeb WP **(C)** applied through irrigation water and **(D)** by a ground sprayer. **(E)** Mancozeb F applied by a ground sprayer.

Table 2. Effect of fungicides applied through irrigation water or with a ground sprayer on a late season crop of Marketer cucumber

Treatment[x]	Rate (kg/ha)	Downy mildew (%)[y]	Foliage discolored or destroyed (%) weeks after planting		No. of fruits rotted (%)	Marketable fruits	
			5	10		%	kg/ha
Mancozeb F							
I	1.79	13 ab[z]	44 a	89 a	17	0 c	0 b
S	1.79	3 cd	30 b	42 d	7	49 ab	1,146 b
Mancozeb WP							
I	1.79	11 abc	44 a	74 b	11	20 bc	120 b
S	1.79	3 cd	28 b	55 cd	8	36 ab	851 b
Chlorothalonil F							
I	2.33	4 cd	28 b	58 c	30	30 b	569 b
S	2.33	1 d	21 b	18 e	7	60 a	4,661 a
Captafol F							
I	3.64	5 bcd	30 b	71 b	8	21 bc	941 b
Control		19 a	49 a	94 a	10	32 ab	77 b

[x] I = fungicides siphoned into the irrigation water, S = applied with a plot boom sprayer or a Myers downdraft sprayer. Treatments were begun 2 wk after planting and continued every 5–9 days for nine applications.

[y] Estimated percentage of leaves with one or more lesions 4 wk after planting.

[z] Numbers in a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. Absence of letters indicates no significant differences.

Table 3. Influence of root-knot nematodes on foliage disease severity, fruit rot, and yield of cucumber

Fungicide (2.33 kg/ha)	Nematicide (5.6 kg/ha)	Root gall index[x]	Foliage discolored or destroyed (%) weeks after planting		Fruit rot[y] (%)	Marketable fruits/ha		
			8	10		%	no.	kg
Chlorothalonil	Phenamiphos	1.55 b[z]	9 b	18 b	6 b	60 a	35,654 a	4,661 a
Chlorothalonil	None	4.10 a	16 b	36 b	20 a	40 ab	11,661 b	1,355 b
None	Phenamiphos	1.35 b	86 a	96 a	5 b	32 ab	897 b	77 b
None	None	2.00 b	92 a	94 a	0 b	7 b	224 b	13 b

[x] 1 = no galls, 2 = 1–25, 3 = 26–50, 4 = 51–75, 5 = 76–100% of all roots galled.

[y] Percentage of total fruits with water-soaked, gray-green lesions.

[z] Numbers in a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$. Absence of letters indicates no significant differences.

Fungicides were applied through the irrigation water or by ground sprayers. For the overhead sprinkler system, the fungicides were mixed into 1 or 2 L of water and siphoned into the irrigation risers through venturi tubes when water was applied 2–4 mm/ha. Foliar sprays were applied with a tractor-mounted boom sprayer or a Myers downdraft sprayer in 187 or 234 L of water per hectare. Fungicides used in one or both tests were chlorothalonil, mancozeb flowable (F) or wettable powder (WP), and captafol.

In the first test, fungicides were applied at flowering and 13 and 20 days later. Fruits were harvested six times at 3- or 4-day intervals beginning 12 days after flowering. In the second test, nine applications were begun 2 wk after planting and were continued at 5- to 9-day intervals. Fruits were only harvested once, 10 wk after planting and 2 days after the last application. Fertilizer was applied at planting and by injection into the irrigation water. Insecticides were applied as needed with ground sprayers.

Marketable fruits were determined according to U.S. Department of Agriculture standards for cucumber (15). The number of rotted fruits from each plot was determined and fungi were isolated and identified from lesions on randomly selected fruits. Plants were rated for foliage disease severity by visually estimating the percentage of discoloration and decay in each plot. In the first test, plants were rated once after the last harvest, but in the second test, ratings were made weekly from 3 wk after planting until harvest, and apparent infection rates were calculated for each treatment (16).

In the second test, phenamiphos was injected into the irrigation system and applied to the experimental area (5.6 kg/ha) 1 day before planting. Before injection, subplots 1.8 × 12.2 m were covered with plastic within the chlorothalonil (applied by ground sprayer) and the control plots. Data were taken on foliar disease and fruit rot severity, yield, populations of nematodes in soil, and root gall indexes in treated and untreated subplots. Roots were rated for galls by using a 1–5 scale with 1 = 0, 2 = 1–25, 3 = 26–50, 4 = 51–75, and 5 = 76–100% of all roots galled.

Rainfall was recorded at a meteorological station approximately 200 m from the plots. All data were analyzed by least squares analysis of variance and by multiple regression (13).

RESULTS

Spring crop. Foliar diseases were not detected in the controls until 3 days before the first harvest, 8 wk after planting. Both gummy stem blight and target spot were identified then, but disease intensity was slight. Foliar destruction was moderate to severe in the controls after six harvests, and the primary disease was gummy stem blight. Precipitation totaling 27.3 cm was recorded on 16 different days. There was no difference in disease control or yield of marketable fruits between fungicides applied through the overhead irrigation and through ground sprayer, but both treatments greatly reduced foliar injury and increased yields compared with the control (Table 1). Stepwise regression analysis indicated that 62% of the variation in marketable weight of cucumber in the six harvests could be explained by the effects of foliar disease as reflected by disease intensity recorded at the final harvest.

Fruit rot incidence was low and ranged from 0 to 10% in the control plots during the six harvests. *R. solani* and *Mucor* spp. were isolated from 50 and 32% of the lesions on rotted fruits, respectively. There were no differences among treatments, but fruit rots were rare in plots treated with chlorothalonil (Table 1).

Fall crop. Downy mildew, gummy stem blight, anthracnose, target spot, and Cercospora leaf spot were identified on the cotyledons and the first two leaves of plants in control plots 20–29 days after planting. An epidemic of downy mildew developed very rapidly in the control plots, and approximately 50% of the foliage was discolored or destroyed 5 wk after planting (Fig. 1). Four separate loci of anthracnose and one locus of target spot were also evident 4 wk after planting in different plots, but these loci were only 2–3 m in diameter 8–10 wk after planting. Thus, five leaf spot pathogens were identified in the experimental area, but > 90% of the foliar destruction was caused by downy mildew. Precipitation on 23 different days totaled 23.5 cm; 19 cm fell on 15 days 3–8 wk after planting.

The apparent infection rate (r) in the control plots was 0.186, 0.059, 0.081, 0.167, 0.143, and 0.039, during the fifth through the 10th week after planting, respectively. The large reduction in r during the sixth week was during a 9-day period of no precipitation. Fungicide treatments did not significantly influence r in the early stages of the epidemic. The epidemic increased very rapidly from 4 to 5 wk in all treatments and then less rapidly from 5 to 10 wk after planting.

Mancozeb WP applied by a ground sprayer and captafol applied through the irrigation water significantly reduced r, compared with the control, during midseason, from 6 to 8 wk after planting. Only chlorothalonil applied with tractor-mounted sprayers reduced r for 3 wk from the sixth through the ninth week after planting. During the full season, from 4 through 10 wk after planting, all fungicide treatments significantly reduced r, compared with the control. Chlorothalonil applied with a ground sprayer gave the best disease control and effectively protected new foliage until harvest (Fig. 1). Chlorothalonil applied through the irrigation water was as effective as ground sprayer applications 5 wk (Table 2) after planting, but the efficacy decreased with time (Fig. 1).

Mancozeb F and mancozeb WP reacted differently depending on the application method. Spray applications of mancozeb WP were more effective in reducing disease severity at harvest than were applications through the irrigation water (Table 2), but the increase in disease severity with time was not influenced by application method. In contrast, mancozeb F was ineffective when applied through the irrigation water, but spray applications were as effective as the WP formulation (Fig. 2, Table 2).

Captafol was not applied with a sprayer, but when applied through the irrigation water, the fungicide was as effective as chlorothalonil until 8 wk after planting. In the late stages of the epidemic, foliar disease severity increased at a greater rate in the plots treated with captafol than in the controls, and more foliage was diseased in plots treated with captafol than in plots receiving chlorothalonil through the irrigation water (Table 2, Fig. 1).

When application methods were compared without regard to fungicide, fungicides applied by ground sprayers lowered r and reduced disease severity, with time, significantly more than fungicides applied through irrigation water. Yields were low in all plots, and only chlorothalonil applied with sprayers increased yields of marketable fruit (Table 2). Fruit rot incidence varied highly among plots, and there were no differences among treatments. Water-soaked, gray-green lesions or sunken reddish brown cankers were observed on 10 and 1.6% of the fruits, respectively. *C. lagenarium, Diplodia* spp., and *Fusarium* spp. were isolated from 58, 26, and 8% of the water-soaked lesions, respectively, and *R. solani* was isolated primarily from cankers.

In subplots treated with phenamiphos applied through irrigation water and chlorothalonil applied with sprayers, the percentage of rotted fruits and root injury by root-knot nematodes was greatly reduced and marketable yields were increased, compared with subplots treated only with chlorothalonil (Table 3). In contrast, when a fungicide was not used, foliar destruction was so severe that nematode control did not influence yields.

DISCUSSION

Our results show that several factors may determine whether fungicides added to overhead irrigation water can successfully control foliar disease. Application of chlorothalonil through irrigation water was equal to application with sprayers to a cultivar with tolerance to downy mildew and other foliar diseases in a spring crop that was not following cucumber. In contrast, in a cucumber multicrop system with a late summer crop and a cultivar susceptible to downy mildew and other foliar diseases, the efficacy of fungicides in irrigation water decreased with time, compared with ground sprayer applications.

In Florida fungicide applications had to be initiated when downy mildew or target spot was first observed for satisfactory disease control on cucurbits (4), and the r for downy mildew in watermelon was over 0.3 in the early stage of an epidemic (10). We began applying fungicides to the susceptible cultivar 2 wk after planting when the first true leaves were developing, but none of the fungicide treatments reduced r until four applications were made.

In contrast, applications of chlorothalonil in the spring test were not begun until flowering, and only three applications were used. Weather conditions were favorable for disease development in both crops, but the initial inoculum levels of foliar disease pathogens were apparently much lower in the spring.

In some foliar diseases, if environmental conditions are favorable for disease development, r increases very rapidly until 5% of the foliage is infected, then lessens, and remains more or less constant until the epidemic runs its course (1). Similar rapid increases in r occurred either when the application of a fungicide was discontinued or when weather favorable to disease followed an interruption or delay of an epidemic. We also observed an extremely rapid increase of downy mildew in the early stages of the epidemic, indicating the importance of beginning a preventive foliar disease control program in cucumber as soon as symptoms are observed and continuing the program until the final harvest. With resistant cultivars in rotation with noncucurbitaceous crops, however, it may be possible to delay or even eliminate fungicide applications during certain growing seasons.

The increase in foliar disease severity and fruit rot, caused by root-knot nematode injury in plots sprayed with chlorothalonil, indicates the importance of an integrated pest management program to insure optimum plant growth and high yields of quality fruits. However, we do not know if the nematicide directly affected fruit rot pathogens or if the fruit rot control was indirect because plant growth and vigor were greater when nematodes were controlled.

Application of a nematicide and fertilizers through irrigation water is feasible on cucumber, but the success of application of fungicides through irrigation water on cucumber depends on the cultivar, the initial inoculum levels of different pathogens, the dilution of the fungicides in the irrigation water, and the retention of the fungicide by the foliage—and probably on the weather. More research is needed on a number of crops and different diseases to determine whether application of fungicides through irrigation water can be a feasible alternative to application with ground sprayers for foliar disease control.

LITERATURE CITED

1. Berger, R. D. 1975. Rapid disease progress in early epidemic stages. (Abstr.) Proc. Am. Phytopathol. Soc. 2:35.
2. Johnson, A. W. 1978. Effect of nematicides applied through overhead irrigation on control of root-knot nematodes on tomato transplants. Plant Dis. Rep. 62:48-51.
3. Johnson, A. W., Sumner, D. R., and Jaworski, C. A. 1979. Effects of management practices on nematode and fungus populations and cucumber yield. J. Nematol. 11:84-93.
4. Jones, J. P. 1978. Disease thresholds for downy mildew and target leafspot of cucurbits and late blight of tomato. Plant Dis. Rep. 62:798-802.
5. McMaster, G. M., and Douglas, D. R. 1976. Fungicide application through sprinkler irrigation systems. Trans. Am. Soc. Agric. Eng. 19:1041-1044.
6. Potter, H. S. 1976. Control of Cercospora leaf spot, Alternaria leaf blight, and bacterial leaf blight of carrot. Fungicide and Nematicide Tests: Results of 1975. 31:83. Am. Phytopathol. Soc., St. Paul, MN.
7. Potter, H. S. 1976. Control of late blight (*Phytophthora infestans*) on potato. Fungicide and Nematicide Tests: Results of 1975. 31:101. Am. Phytopathol. Soc., St. Paul, MN
8. Potter, H. S. 1978. Fungigation for control of *Cercospora* leaf spot on sugar beet, 1976. Fungicide and Nematicide Tests: Results of 1977. 33:64-65. Am. Phytopathol. Soc., St. Paul, MN
9. Potter, H. S., and Kidder, E. H. 1978. Comparison of air and ground methods of applying fungicides for control of early blight and botrytis vine rot of potato, 1976. Fungicide and Nematicide Tests: Results of 1977. 33:84-85. Am. Phytopathol. Soc., St. Paul, MN
10. Schenck, N. C. 1968. Fungicidal control of watermelon downy mildew and its relationship to first infection in the field. Plant Dis. Rep. 52:979-981.
11. Sitterly, W. R. 1969. Effect of crop rotation on cucumber gummy stem blight. Plant Dis. Rep. 53:417-419.
12. Skinner, R. E. 1980. Irrigation survey, 1979. Univ. Ga. Coop. Ext. Serv. Loose leaf, mimeograph letter.
13. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York. 481 pp.
14. Sumner, D. R., and Smittle, D. 1976. Etiology and control of fruit rot of cucumber in single harvesting for pickles. Plant Dis. Rep. 60:304-307.
15. U.S. Department of Agriculture, Agriculture Marketing Service. 1978. United States standards for cucumber. Washington, DC. 7 pp.
16. van der Plank, J. E. 1963. Plant Diseases: Epidemics and Control. Academic Press, New York. 349 pp.