CUCUMBER FUNGICIDES FOR THE WEST COAST OF FLORIDA

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Florida is now producing 40 percent of the total production of cucumbers for fresh market in the United States (1). During the past five years, the average yield per acre has doubled and the value of the crop has more than tripled the average for the previous five years. The use of more effective fungicides on cucumbers, as the result of fungicide testing by the Florida Agricultural Experiment Stations, has been a major factor in the increased yields obtained by Florida growers.

Cucumber fungicide testing by the Florida Stations has been in progress for many years. Weber (13), one of the pioneer workers in this field, recommended Bordeaux mixture or copper-lime dust. Later, Harrison and Kelbert (5,6) and Harrison (7) reported that some of the organic fungicides and the neutral copper fungicides were less injurious to cucumbers than was Bordeaux mixture. Wilson and Swank (14) reported than nabam + $ZnSO_4$, nabam + $MnSO_4$, and maneb provided excellent control of downy mildew while mildex, nabam + $MnSO_4$, and maneb gave the best control of powdery mildew. Walter (12) found that nabam + $ZnSO_4$ gave entirely satisfactory control of both mildews in his test. The results of cucumber fungicide testing in Florida have closely paralleled the work of Epps (3,4) in South Carolina. This worker, after conducting fungicide tests on cucumber for ten years, has concluded that maneb is the superior fungicide for this crop in that area. Zineb is also recommended in South Carolina, being only slightly less effective than maneb.

GENERAL MATERIALS AND METHODS

Throughout the investigation reported in this paper, cucumbers of the variety Marketer were used. The fungicides were applied with commercial-type sprayers adapted to small plot work. TeeJet 8002 nozzles were used with pressures at the pump of from 300 to 400 p.s.i.

The fungicides were used at the following concentrations per 100 gallons unless otherwise stated: 2 qts. 19% nabam + ¾ lb. 36% $ZnSO_4$; 2 qts. 19% nabam + 1 lb. 32% $MnSO_4$; 2 lbs. 65% zineb; 1½lbs. 70% maneb; 4 lbs. 50% captan or 4-6 lbs. neutral copper (2 lbs. metallic copper).

SOIL ROT

The primary objective in fungicide testing on cucumbers at the Gulf Coast Station during recent years has been the development of a satisfactory control of soil rot, which has caused increasingly serious losses to cucumbers on the West Coast of Florida. Estimated losses of up to 30 percent of the crop were reported during years when conditions were favorable to the disease. In individual fields, losses may represent as much as 90 percent of the crop. A number of growers have stopped growing cucumbers because of losses from soil rot.

The disease has been attributed to *Pythium* sp. by Walter (12) and to *Rhizoctonia solani* by Weber and Owen (unpublished) in Florida and Ellis (2) in North Carolina. The writer (10,11) has consistently isolated from lesions on cucumber fruits a fungus which is apparently identical to *R. solani*. He has never isolated *Pythium* even when techniques especially adapted to the isolation of *Pythium* have been employed. Inoculation of healthy fruits with isolates of *R. solani* resulted in typical lesions.

Previous to the beginning of the research reported here, Walter (12) had shown that neutral copper, captan and Terraclor were the most promising fungicides for the control of soil rot. Consequently these materials received primary attention in recent research. The percentages of fruits showing infection were determined and converted to angles for statistical analysis as described by Snedecor (9).

In the spring of 1955, a cooperative test was conducted by Dr. J. M. Walter and the writer. The copper fungicides were applied

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once a week at the recommended concentration as a foliage fungicide and as a heavy spray application of 58 pounds per acre to the soil just before the plants began to vine. The heavy spray application was made by using the recommended concentration of the fungicide in water and repeatedly spraying the surface of the beds with this suspension until the prescribed amount of fungicide was deposited. Six nozzles were used per row to cover the entire soil surface with the exception of the furrows between the beds. Two neutral copper fungicides, Tennessee Tribasic Copper Sulfate and Cop-O-Zink, reduced soil rot to one-half the amount present in check plots sprayed with nabam + $ZnSO_4$ (Table 1). The combination treatment involving the application of Terraclor as a preplanting drench and a heavy spray application of captan (58 pounds of Orthocide 50-W per acre) was equally effective. The Terraclor drench was applied at the rate of 25 pounds of active ingredient per acre. This treatment alone had no effect on the amount of soil rot; so it seems likely that the effectiveness of the combination treatment was due to the captan. Captan applied once a week, alternating with nabam + $ZnSO_4$ as a foliage fungicide, also significantly reduced soil rot.

During the fall of 1955 in a similar experiment, the method of applying the fungicides to the soil was changed to make it more practical for the grower. Instead of using a very high gallonage of the fungicides at the recommended low concentration, the captan and copper were used at the rate of 8 pounds active or 8 pounds metallic copper per 100 gallons. These sprays were applied at 200 gallons per acre. Consequently, 32 pounds of commercial material were applied per acre. Plants sprayed with a concentrated spray application of captan and, in addition, receiving captan alternating with nabam + $ZnSO_4$ each week as foliage applications, yielded only 2 percent diseased fruits. (Table 1). A schedule of captan alternating with nabam + $ZnSO_4$ each week resulted in 9 percent diseased fruits as compared to 19 percent in the check plots, which received nabam + $ZnSO_4$ twice weekly. The combination treatment of Terraclor and captan again reduced the disease by a significant amount. The use of captan (2

Table 1. Control of soil rot by foliage and soil applications of fungicides.

Weekly Foliage Treatment[1]	Soil Treatment, Amount Per Acre	Infected Fruits Total Angle[2]	Infected Fruits Percent
Spring 1955 Test			
Nabam + $ZnSO_4$ alternating with neutral copper (Trib.Cop.sulfate)	Heavy spray application of neutral copper (58 lbs. Tribasic Copper Sulfate)	530	6.8
Nabam + $ZnSO_4$ alternating with neutral copper (Cop-O-Zink)	Heavy spray application of neutral copper (58 lbs. Cop-O-Zink)	562	7.2
Nabam + $ZnSO_4$, alternating with captan (4 lbs. Orthocide 50-W)	None	606	8.4
Nabam + $ZnSO_4$ twice weekly	None	765	13.8
Nabam + $ZnSO_4$ twice weekly	Vapam (25 lbs.active) as pre-planting drench	922	18.7
Nabam + $ZnSO_4$ twice weekly	Terraclor (25 lbs.active) as pre-planting drench	734	12.2
Nabam + $ZnSO_4$ twice weekly	Terraclor (25 lbs. active) as pre-planting drench + heavy application of captan (58 lbs.Orthocide 50-W)	502	5.8
Least significant difference, 5% level		120	
Least significant difference, 1% level		160	
Fall 1955 Test			
Nabam + $ZnSO_4$ twice weekly	None	102.4	18.7
Nabam + $ZnSO_4$ twice weekly	Concentrated spray of neutral copper (32 lbs. Tribasic Copper Sulfate)	75.7	10.3
Nabam + $ZnSO_4$ twice weekly	Pre-emergence drench of Terraclor (25 lbs. active) + concentrated spray of captan (32 lbs.Captan 50-W)	72.6	9.8
Nabam + $ZnSO_4$ alternating with captan (4 lbs. Captan 50-W)	Concentrated spray of captan (32 lbs.Captan 50-W)	27.9	1.5
Nabam + $ZnSO_4$ alternating with captan (4 lbs.Captan 50-W)	None	69.8	8.9
Nabam + $ZnSO_4$ + captan (2 lbs. captan 50-W) twice weekly	None	79.6	11.6
Nabam + $ZnSO_4$ alternating with neutral copper (Tribasic Copper Sulfate)	None	80.2	11.7
Neutral copper twice weekly (CW2)	None	72.3	9.6
Least significant difference, 5% level		26.8	

[1]Concentrations used were those specified by the manufacturer unless others are listed.
[2]The percentages of fruits showing soil rot were converted to angles and analyzed as directed by Snedecor (9).

pounds of Captan 50-W) mixed in the tank with reacted nabam + $ZnSO_4$ failed to control the disease. All the copper treatments with the exception of the twice-weekly foliage application failed to control the diseases in this experiment. Even though the twice-weekly application of copper significantly reduced soil rot, it resulted in significantly lower yields (Table 2). This may be explained by the failure of this fungicide to effectively control downy mildew and by the toxicity of copper to the cucumber plant.

In tests conducted in the spring of 1956, John Bean nozzles equipped with No. 2½ discs were used. These nozzles have a delivery rate of exactly three-fourths that of the TeeJet 8002 nozzles previously used. This means that even though the same rate of materials was used in this experiment, only three-fourths as much active ingredient was applied per acre. It was obvious after the first picking that the formerly effective materials were completely failing to control soil rot. The most logical explanation of this result seemed to be that less material per acre was used here than previously. To test this hypothesis, plots in a separate experiment were sprayed with a concentrated application of captan. The sprayer was equipped with TeeJet 8002 nozzles. By the next picking, soil rot was reduced from 30 percent in the untreated plots to 17 percent in the captan-treated plots. This difference was even more pronounced at the later pickings. During the four pickings after treatment, the captan plots yielded 14 percent infected fruits while the untreated plots yielded 28 percent. The importance of using an adequate rate of captan per acre is clearly illustrated by these data. At least 16 lbs. of active ingredient must be applied per acre. This means that the grower must use at least 16 lbs. of captan 50-W or Orthocide 50-W per 100 gals. water and at least 200 gals. of this spray per acre.

Downy Mildew

Downy mildew (*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow.) is the most serious disease of cucumbers in Florida. The pathogen, which apparently survives from one season to the next, is present during periods favorable to development of the fungus whenever cucumbers are grown in the State. The destructiveness of this disease is reflected by the fact that unsprayed plots have largely been omitted in fungicide tests because of the early-season death of unprotected plants. Very seldom can mature cucumbers be picked from unsprayed plants in the West Coast area.

Observations on downy mildew control have been made in all cucumber fungicide tests conducted at the Gulf Coast Experiment Station. Not until the fall of 1955, however, was a concerted effort made to evaluate the relative value of twice-weekly applications of the highly effective carbamate fungicide and neutral copper. Downy mildew control was evaluated by the grading system pro-

Table 2. Downy mildew control as rated by Horsfall and Barratt's grading system and yield of cucumbers during the Fall 1955 crop season

Treatment	Disease Severity		Yield	
	Total infection grade	Percent leaf area affected	Lbs. per plot	Bu. per acre
1. Maneb twice weekly	5	3.0	137.5	560
2. Nabam + $ZnSO_4$ twice weekly	7	5.0	152.5	621
3. Nabam + $MnSO_4$ twice weekly	9	7.0	92.0	375
4. Zineb twice weekly	10	8.5	104.7	427
5. Neutral copper (C'Z) twice weekly	16	23.5	64.8	264
7. Nabam + $ZnSO_4$, alternating with captan (4 lbs.captan 50-W)	8	6.0	104.9	427
8. Nabam + $ZnSO_4$, alternating with neutral copper (Tribasic Copper Sulfate)	10	8.5	86.7	353
Least sig.difference, 5% level	3.6		32.2	
Least sig.difference, 1% level	4.9		43.3	

posed by Horsfall and Barratt (8). In this test, the recommended carbamate fungicides, nabam + $ZnSO_4$ and zineb, as well as maneb and nabam + $MnSO_4$, were superior to a neutral copper fungicide (Table 2). Zineb used twice weekly, neutral copper alternating with nabam + $ZnSO_4$ each week, and nabam + $MnSO_4$ twice weekly were significantly inferior to maneb. Yield differences followed the same pattern, being closely related to differences in downy mildew control. The nabam + $ZnSO_4$ and maneb plots gave the highest cucumber yields. The inferior performance of zineb in this experiment is difficult to understand. Conclusions should not be drawn regarding the difference between nabam + $ZnSO_4$ and zineb until this experiment is repeated using several formulations of zineb. The important point to consider is the superior performance of maneb, which should be added to the list of recommended cucumber fungicides. Neutral copper has not been recommended for control of downy mildew for several years, but still remains as the only material recommended against angular leafspot.

Powdery Mildew

Powdery mildew (*Erysiphe chicoracearum* DC.) seldom damages cucumbers on the West Coast of Florida when the plants are properly sprayed for downy mildew. The sporulation of this fungus is so conspicuous that it may conceal damage caused previously by downy mildew. It is believed that the damage done by the powdery mildew fungus has been exaggerated because of the conspicuous nature of the pathogen.

Experiments on powdery mildew control were conducted at the Gulf Coast Station for the last three years, but the light incidence of disease prevented a critical comparison of the effective chemicals. In the spring of 1956, several inoculation procedures were followed in attempts to establish the disease in the experimental field. Cantaloupe leaves on which the pathogen was sporulating were rubbed through the dry leaves of plants in several areas of the unsprayed guard rows of the plots. At the same time, cucumber seedlings growing in flats were inoculated with spores from the same material. As soon as the cucumber seedlings showed symptoms of infection, the flats were moved to the field and placed at several locations among the plants growing in the guard rows. Within several weeks, the fungus appeared on the inoculated plants and spread to adjacent plants in the guard rows. The inoculations were begun too late in the season for maximum infection, but the technique was shown to be successful. In experiments on powdery mildew control, adequate control of downy mildew is necessary if the plants are to survive long enough to permit the evaluation of disease control. Consequently in the 1956 spring test, the materials for powdery mildew control were to be incorporated with the maneb when powdery mildew appeared in the plot rows. Since the fungus did not spread from the inoculated plants on the guard rows to the maneb-sprayed plot rows, the test materials were not used. Maneb gave satisfactory control of powdery mildew under the conditions of this experiment.

In a series of greenhouse screening tests, an attempt was made to evaluate the potentialities of the antibiotic, griseofulvin, in the control of powdery mildew. Marketer cucumbers were grown in pots containing fumigated soil until they had produced a single true leaf. At this time the plants were showing a uniformly light infection of powdery mildew. They were sprayed with the following fungicides; Karathane, 8 ozs. per 100 gals.; wettable sulfur, 2 lbs. per 100 gals.; 70% maneb, 1½ lbs. per 100 gals.; or 500 p.p.m. griseofulvin. One percent griseofulvin dust was also used.

Six days after treatment, the amount of leaf area covered by the fungus was evaluated by the grading system proposed by Horsfall and Barratt (8). Karathane, wettable sulfur and maneb gave a high degree of control (Table 3). Griseofulvin, applied as either a dust or spray, also reduced the disease by a highly significant amount but was significantly inferior to the other materials.

Many objections have been raised to the attempted application of greenhouse fungicide tests to field conditions. The writer believes, however, that with discrimination in interpreting results and the inclusion of several standards of varying efficiency in disease control, greenhouse screening tests will provide information to eliminate much unnecessary field testing of mediocre materials. The performance of griseofulvin in the above test

Table 3. Powdery mildew control in greenhouse screening test, as evaluated by Horsfall and Barratt's grading system

Treatment	Infection Grade Replication 1	2	3	4	Total	Leaf Area Affected Percent
Karathane, 8 ozs. per 100 gal.	0	0	1	1	2	1.0
Sulfur (wettable) 2 lbs.per 100 gal.	1	1	0	0	2	1.0
Maneb, 1.5 lbs.Manzate per 100 gal.	1	1	1	1	4	2.0
Griseofulvin dust, 1%	3	2	4	5	14	17.0
Griseofulvin spray, 500 p.p.m.	3	2	3	3	11	10.0
Check, no treatment	5	6	5	5	21	44.0
Least significant difference 5% level					4.2	
Least significant difference 1% level					5.8	

raises a serious question as to whether further testing of this material against powdery mildew is justified.

In another greenhouse test 10 percent Ovex (p-chlorophenyl p-chlorobenzene - sulfonate) was as effective as Karathane in protecting plants against powdery mildew. Wettable sulfur and maneb were only slightly less effective. The performance of Ovex, relative to materials known to control the disease in the field, is a strong indication that this new fungicide should be tested further.

Summary and Conclusions

Soil rot of cucumber has been significantly reduced by the use of 32 pounds of 50 percent captan per acre as a single concentrated spray applied when the plants are young or when the disease appears. Captan controlled the disease also when applied weekly at 2 lbs. (active) per 100 gals. of water, alternating with nabam + $ZnSO_4$. While this schedule gave an excellent control of downy mildew during one season, it may not give satisfactory control of this disease during severe epiphytotics.

Maneb and nabam + $ZnSO_4$ have given superior performance in the control of downy mildew and in yield of marketable cucumbers. The neutral copper fungicides should not be used for downy mildew control on cucumbers. Maneb controlled powdery mildew under conditions of moderate disease development. Greenhouse screening tests have shown that while griseofulvin will significantly reduce the amount of powdery mildew it does not compare in effectiveness with the synthetic materials. Karathane and Ovex were outstanding in their performance against powdery mildew in greenhouse screening tests.

Literature Cited

1. Brooke, D. L. Statistics on production, shipments and prices of Florida cucumbers. Fla. Agr. Exp. Sta. Agr. Econ. Mimeo. Rep. 56-9. 1956.
2. Ellis, D. E. Noteworthy diseases of cucurbits in North Carolina in 1949 and 1950. Plant Dis. Rep. **35**:91-93. 1951.
3. Epps, W. M. An evaluation of fungicides for the control of cucumber diseases in South Carolina. Clemson College Dept. of Bot. Mimeo. Series No. 2, 1956.
4. Epps, W. M. An evaluation of fungicides for the control of diseases of cucumbers in South Carolina. Plant Dis. Rep. **40**:441-442. 1956.
5. Harrison, A. L. and Kelbert, D.G.A. Miscellaneous pathological observations. In Fla. Agr. Exp. Sta. Ann. Rep. **1944**:116.
6. ———— Organic fungicides for the control of foliage diseases of vegetables. In Fla. Agr. Exp. Sta. Ann. Rep. **1945**:121-122.
7. Harrison, A. L. Test on some new organic fungicides. Proc. Fla. State Hort. Soc. **58**:232-235. 1945.
8. Horsfall, J. G. and Barratt, R. W. An improved grading system for measuring plant diseases. Phytopath, **35**:655. 1945. (Abstract)
9. Snedecor, G. W. Transformations of data for test of significance. In Statistical Methods pp. 445-451 Iowa State Col. Press, Ames, Iowa. 1950.
10. Sowell, G. Jr. Etiology of soil rot of cucumber. In Fla. Agr. Exp. Sta. Ann. Rep. **1955**. 286.
11. ————. Etiology and control of soil rot of cucumber. Phytopath. **46**:27. 1956. (Abstract)
12. Walter, J. M. Organic fungicides for the control of foliage diseases of vegetables. In Fla. Agr. Exp. Sta. Ann. Rep. **1953**:278-279.
13. Weber, G. F. Cucumber diseases in Florida. Fla. Agr. Exp. Sta. Bul. 208. 1929.
14. Wilson, J. W. and Swank, G. Jr. Synthetic insecticides and fungicides for vegetable crops in central Florida. In Fla. Agr. Exp. Sta. Ann. Rep. **1953**: 173-174.