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FUNGICIDES FOR THE CONTROL OF EARLY BLIGHT ON CELERY

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Industrial expansion of agricultural research during the last decade has made available to Experiment Station pathologists many new synthetic organic fungicides for testing against a varied group of fungi affecting a wide range of crops. Many excellent fungicides are on the market today. Nevertheless, it is the aim of all research personnel concerned with pesticides to obtain a material that has a greater fungicidal potential, costs less, is easier to apply and has greater residual value. These are the basic reasons for an existing program which involves the testing and evaluation of pesticides.

Before presenting experimental results of the use of fungicides for the control of early blight on celery, it seems advisable to mention factors which influence the development of this disease. At no time during the past five years has the disease become severe during December or January. The question immediately arises, "why has the disease failed to develop during these months?"

It is well known that such factors as inoculum, temperature, susceptible host, moisture and many others influence the development of the disease. However, a review of the data concerning these factors showed moisture to be the most important. It seems apparent, therefore, that the number of fungicide applications necessary to control early blight is largely determined by available moisture. At best, only a tentative spray schedule for disease control can be suggested. The responsibility of adjusting a disease control program to conform with existing conditions is the individual grower's problem.

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During the past two years, thirty-five fungicidal formulations were compared for the control of *Cercospora apii* Fr., the organism causing early blight of celery. Data reported herein are the results of several experiments conducted during that period.

METHODS AND RESULTS

Celery seedlings, of the variety Abbott & Cobb Early Fortune, were transplanted from seedbeds to the field on November 20, 1951. The planting was divided into six blocks, with each block being subdivided into plots. A plot consisted of three rows, 40 feet long with 30 inch spacing. Each was randomized and replicated six times, and data were obtained from the center row. Cultural methods, including fertilizer and irrigation practices, were representative of those in the area. Insecticides were applied in combination with the fungicides, as needed. Beginning on December 7, 1951 fungicides were applied with a power sprayer and continued weekly thereafter for a period of fifteen weeks. Three Tee Jet, fan-shaped nozzles with an opening of 6503 and a 50 mesh screen were used per row. These were so placed that one sprayed directly over the row and one on either side at a 90° angle. The side nozzles were suspended on a flexible rubber hose approximately 3 inches above the soil line. One hundred gallons of spray mixture was applied per acre.

Disease incidence was rated on a scale of 1 through 7, with 1 indicating little or no disease and 7 a severe infestation. For example, a treatment rated 4 had a considerable number of lesions on the lower half of the plant and a few lesions on the top foliage. Three ratings were averaged for the final disease score. Materials, formulae, disease ratings, yield and number of stalks infected with *Sclerotinia sclerotiorum* (Lib.) Mass. are presented in Table 1.

Table 1. Results of fungicide spray trials on golden celery during the winter of 1951-52. Averages of six replicates.

Materials	Formula Used	Early Blight Rating	No. of Stalks Infected With Pink Rot/40 Ft. of Row	Wt. in Lbs. of Marketable Celery/40 Ft. of Row
1. Mathieson 466*	1.5 - 100	4.87	4.0	91.83
2. Tri-Basic Copper Sulfate	4 - 100	1.71	.6	106.50
3. Robertson Copper	2 - 100	3.16	1.0	110.50
4. Copper A	4 - 100	2.71	2.2	97.83
5. Cop-O-Zinc	4 - 100	3.29	1.4	119.50
6. Mathieson 466*	3 - 100	3.50	4.6	69.00
7. Mathieson 916*	3 - 100	3.58	1.0	96.16
8. Bioquin	1.5 - 100	3.58	2.4	105.83
9. Bordeaux Mixture	6 - 4 - 100	1.96	3.4	99.00
10. Dithane D-14 plus Zn SO_4 (Nabam)	2 + 3/4 - 100	1.25	17.8	100.30
11. Parsate plus Zn SO_4 (Nabam)	2 + 3/4 - 100	1.37	22.0	96.50
12. Z-78, old formulation (Zineb)	2 - 100	3.66	8.2	87.00
13. Manzate	1.5 - 100	1.41	18.4	104.80
14. Z-78, new formulation (Zineb)	2 - 100	3.64	6.0	95.00
15. Zerlate (Ziram)	2 - 100	2.61	3.0	94.50
16. Fermate (Ferbam)	2 - 100	1.45	2.6	103.83
17. Phygon XL	3/4 - 100	4.87	21.6	78.50
18. Captan 75%	3 - 100	4.95	9.6	90.30
19. Alternate 2 and 10	4 - 2 - 100	1.20	17.0	100.80
20. Alternate 2 and 15-16	4 - 1 - 1 - 100	1.04	4.2	111.50
21. Untreated	----	7.00	8.2	77.16
L.S.D. 5% Level		0.55	8.13	20.61
1% Level		0.74	10.78	27.28

* Experimental fungicides of Mathieson Chemical Corporation.

Of the eight copper fungicide formulations, only Tri-Basic Copper Sulfate and Bordeaux Mixture controlled the disease satisfactorily. The other copper formulations, when compared with each other, gave approximately the same degree of blight control, with Copper A being somewhat more effective. All materials greatly reduced blight when compared with untreated plots. With approximately equivalent amounts of metallic copper used, the difference in degree of control of the various materials must have been due to the degree of solubility, particle size, wetting agents, conditioning agents, or adhesives used in formulating the material. Only repeated tests using many formulations can determine which factor or combination of factors is the answer, as many of these factors appear to be important in determining the effectiveness of a given fungicide.

Of the carbamates, nabam + zinc sulfate, Manzate, and ferbam gave superior control of early blight. Nabam + zinc sulfate was superior in disease control, when compared with two wettable powder formulations of zineb. Ziram, when used alone, was not as effective as ferbam.

Phygon XL gave poor early blight control, and caused yellowing and stunting early in the growth of the plants. Captan, while effective during the early part of the season, did not control the disease toward the end of the test.

Mention should be made of the fact that a straight nabam schedule on celery will result in an increase of pink rot. This has been observed many times and experimental data confirm the observations. Thus, even though nabam is one of the better fungicides for the control of early blight, it should not be used as the only fungicide on celery.

More effective control of early blight and pink rot has been obtained by alternating a mixture of ziram and ferbam with a fixed copper. This program has been tested repeatedly in experimental plots and used in commercial plantings with good success.

Early blight did not develop until late in the experiment, the disease readings being made only two weeks before harvest. Consequently, the yield data (Table 1) do not reflect closely difference in disease control.

A second test, Table 2, wherein polyethylene polysulfide (P.e.p.s.) was used as a spreader-sticker with Tri Basic copper sulfate or ziram plus ferbam at intervals of one, two and three weeks, indicated the interval of fungicide applications may be lengthened during the winter months. Plots sprayed at weekly intervals were almost free of the disease and only a slight increase in disease development was observed at the two week interval. The increase in diseased foliage between the two and three week interval plots was considerably less in plots sprayed with Tri-Basic Copper Sulfate and P.e.p.s. This suggests that ziram and ferbam break down more readily under long exposure than do fixed coppers.

Table 2. Effect of a variable spray interval on early blight control in 1951-52 season.

Materials	Interval Between Application	Formula Used	Early Blight Rating	Wt. in Lbs. of Marketable Celery/40 Ft. of Row
Tri-Basic Copper Sulfate plus Polyethylene Polysulfide	1 week	4 - 1 - 100	1.08	100.00
Do	2 weeks	4 - 1 - 100	1.75	99.16
Do	3 weeks	4 - 1 - 100	2.00	90.00
Ziram and Ferbam plus Polyethylene Polysulfide	1 week	1 - 1 - 1 - 100	1.29	113.33
Do	2 weeks	1 - 1 - 1 - 100	1.70	100.00
Do	3 weeks	1 - 1 - 1 - 100	2.63	99.00

Table 3. Effect of varying the number of nozzles on early blight control during 1951-52 season with a mixture of ziram and ferbam alternated with Tri-Basic Copper Sulfate.

Formula Used	No. of Nozzles per Row	Early Blight Rating	Wt. in Lbs. of Marketable Celery/40 Ft. of Row
1 - 1 - 100 4 - 100	1	5.90	84.66
1 - 1 - 100 4 - 100	3	1.12	102.16
1 - 1 - 100 4 - 100	5	1.16	99.16

A third test, Table 3, in which the number of nozzles per row were varied, showed significant differences. An identical arrangement of nozzles was used as described for Experiment I, but with two additional nozzles, one placed on either side spraying toward the row at 45° angle. Significantly better disease control was obtained where three and five nozzles were used as compared with one nozzle. No difference in disease control was observed between the three and five nozzle arrangement. Since equal quantities of the active ingredient were applied, the difference in disease control was due to a more thorough distribution or coverage of the foliage.

During the 1952-53 season, tests were again conducted, using a similar arrangement as described for Experiment I in 1951-52. Hollow-cone nozzles with a No. 2 flat disc orifice were substituted for the flat-fan nozzles of the previous year.

Celery seedlings, of the variety Florida Golden No. 15, were transplanted to the field on December 7, 1952. The first application of fungicides was applied on January 13 and weekly thereafter for a period of ten weeks. Comparison of materials for their effectiveness in controlling *C. apii* again followed the trend of results obtained during the previous year. Data presented in Table 4 show manzate, nabam + zinc sulfate, nabam plus manganese sulfate, Tri-Basic Copper Sulfate and a mixture of ziram and ferbam superior to other materials. Manganese ethylene bisdithio carbamate prepared as a tank mix by adding nabam to manganese sulfate was slightly inferior, but not significantly so, to the wettable powder formulation for blight control.

Again during the 1952-53 season, plots receiving only nabam + zinc sulfate or manganese sulfate had a greater number of stalks infected with pink rot as indicated by the lower yield record.

A second experiment, Table 5, designed to compare the effectiveness of spreader-stickers when used in combination with the same fungicides, showed considerable differences in the degree of blight control. Weekly applications

of P.e.p.s., National, and Triton B-1956 spreader-stickers, showed significantly better control of early blight than Vancide Sticker when used in combination with Tri-Basic Copper Sulfate or a mixture of ziram and ferbam. On a bi-weekly interval the combination of

Table 4. Results of fungicide spray trials on golden celery during the winter of 1952-53. Averages of six replicates.

Material	Formula Used	Early Blight Rating	Wt. in Lbs. of Marketable Celery per 40 Ft. of Row
Tri-Basic Copper Sulfate	4 - 100	2.05	134
Manzate	1½ - 100	1.05	132.5
Dithane D-14 Zinc Sulfate	2 - 3/4 - 100	1.24	122.6
Dithane D-14 Manganese Sulfate	2 - 1 - 100	1.35	121.2
Lo 765*	2 - 100	3.19	131.8
Lo 765	3 - 100	2.89	129.8
B.F.G. 35 D**	2 - 100	3.89	121.5
Zerlate Fermate	1 - 1 - 100	1.77	135.2
Captan	3 - 100	3.23	130.0
Vancide 51 ZW	2 - 100	2.85	140.3
Vancide 51 Mn	2 - 100	3.02	128.8
48 - CS - 36***	2 - 100	5.99	107.5
48 - CS - 73***	2 - 100	6.19	100.0
Untreated	----	6.88	92.8
L.S.D. 5% 1%		0.42 0.56	13.5 18.0

* Experimental fungicide of Rohm & Haas Company.
** Experimental fungicide of B. F. Goodrich Chemical Company.
*** Experimental fungicide of Velsicol Corporation.

Table 5. Results of fungicide spray trials on golden celery during the 1952-53 season. Average of five replicates.

Trade Names of Fungicides and Stickers	Application	Formula Used	Early Blight Rating	Wt. in Lbs. of Marketable Celery/40 Ft. Row
1. Tri-Basic Copper Sulfate* plus Vancide Sticker or Zerlate and Fermate plus Vancide Sticker	Weekly	4 - 1 pt. - 100 1 - 1 - 1 pt. - 100	2.43	135.0
2. Tri-Basic Copper Sulfate plus polyethylene polysulfide or Zerlate and Fermate plus polyethylene polysulfide	Weekly	4 - 1 pt. - 100 1 - 1 - 1 pt. - 100	1.36	131.0
3. Tri-Basic Copper Sulfate plus polyethylene polysulfide or Zerlate and Fermate plus polyethylene polysulfide	Bi-weekly	4 - 1 pt. - 100 1 - 1 - 1 pt. - 100	2.76	135.0
4. Tri-Basic Copper Sulfate plus National Sugar Sticker or Zerlate and Fermate plus National Sugar Sticker	Weekly	4 - 1 qt. - 100 1 - 1 - 1 qt. - 100	1.86	129.8
5. Tri-Basic Copper Sulfate plus B-1956 or Zerlate and Fermate plus B-1956	Weekly	4 - 6 oz. - 100 1 - 1 - 6 oz. - 100	1.45	122.2
6. Tri Basic Copper Sulfate plus B-1956 or Zerlate and Fermate plus B-1956	Bi-weekly	4 - 6 oz. - 100 1 - 1 - 6 oz. - 100	3.79	104.4
L.S.D. 5% 1%			0.45 0.62	21.33

*Fungicides were alternated weekly.

P.e.p.s. and Tri-Basic Copper Sulfate or ziram and ferbam was significantly better than Triton B-1956 and the same fungicides. Thus again, as in the 1951-52 trials, data indicate the interval between spray applications can be lengthened with the addition of a suitable spreader-sticker to the spray mixture.

Of the many new compounds tested, only one, Manzate, controlled early blight as effectively as the fungicides now recommended.

SUMMARY

Early blight of celery caused by *Cercospora apii* has not been important during the months of December and January for the past five years. The failure of the disease to develop was probably due to low rainfall during this period.

In the 1951-52 and 1952-53 seasons the following gave superior early blight control: Tri-Basic Copper Sulfate, Bordeaux Mixture, nabam, Manzate, ferbam, or alternate applications of Tri-Basic Copper Sulfate and ziram and ferbam or alternate applications of Tri-Basic Copper Sulfate and nabam.

Nabam + zinc sulfate was superior to the wettable powder zineb.

The addition of polyethylene polysulfide (P.e.p.s.) to recommended fungicides indicates that the time interval between applications may be extended without affecting disease control.

Three and five nozzles per row provided better spray coverage of the plant foliage than did one nozzle, and better disease control, but no difference was apparent between three and five nozzles per row.

Pink rot increased when only nabam + zinc sulfate was used during the spray schedule.

THE EFFECT OF COPPER ON NITRIFICATION IN SOME FLORIDA SOILS

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During the past few years several reports have been made concerning the accumulation of copper in soils upon which citrus and truck crops are being produced in Florida. Reuther and Smith (6) found concentrations of copper as high as 480 to 640 pounds per acre in old citrus groves in the vicinity of Orlando; while Stewart and Leonard (9) reported 200 to 400 pounds of copper per acre in certain plots at the Citrus Experiment Station, Lake Alfred, Florida. Westgate (10), working with soils in the vicinity of Sanford, found old celery fields which contained 168 to 422 p.p.m. total copper. These concentrations are in striking contrast to that present in the virgin soils of the same areas. Rogers et al. (8) found less than 10 p.p.m. of copper in the virgin soils.

Recently, certain irregularities in plant growth have been correlated with large amounts of copper in the soil. Westgate (10) indicated that high total copper in the soil was associated with iron chlorosis, brown stubby roots, and stunting of sweet corn. He also found that some poor celery seed beds with severe stubby root, which have not responded to soil fumigation, contained as high as 1654 p.p.m. copper in the surface-inch of soil.

Among the several factors which may have an important bearing on the incidence of iron chlorosis in citrus groves, Reuther and Smith (6) stated that excessive accumulation of copper in the soil is probably a major factor and low pH of the soil undoubtedly greatly aggravates the toxicity of this element by increasing its availability. Reuther and Smith (7) showed that a high proportion of the copper applied experimentally to some field fertilizer plots during approximately seven years could be found in the topsoil by total analysis at the end of the period. They stated that accumulation of copper in commercial orchards is the result of the practice, common for more than a decade, of applying mixed fertilizers containing sufficient copper sulfate to add 10 to 25 pounds of copper per acre annually to mature Florida citrus groves. In addition, fungicidal sprays may provide 5 to 15 pounds an acre each year.

Peech (4), Jamison (2), and Lucas (3) found that copper availability is related to soil pH. Jamison believed fixation of copper in acid soils must be due to the formation of slowly soluble organic compounds, and when

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