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MIXTURES OF COPPER AND MANEB OR MANCOZEB FOR CONTROL OF BACTERIAL SPOT OF TOMATO AND THEIR COMPATIBILITY FOR CONTROL OF FUNGUS DISEASES[1]

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Abstract. **Combinations of basic copper sulfate (BCS) and maneb or mancozeb were significantly more effective for control of bacterial spot** (Xanthomonas campestris **pv.** vesicatoria **(Doidge) Young** et al.) **of tomato than BCS by itself. Combinations of BCS with anilazene or captafol were no more effective than BCS alone. Copper-zinc chromate was less efficacious than BCS when combined with maneb or mancozeb. BCS combined with maneb or mancozeb was less effective than maneb or mancozeb alone for control of late blight** (Phytophthora infestans **(Mont.) dBy.) and gray leaf spot** (Stemphylium solani **Weber) of tomato but was more effective than BCS alone.**

Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria* (Doidge) Young *et al.*) has been a very serious disease of the tomato in Florida for more than 40 years. It is probably the most difficult to control of all the fungal and bacterial diseases that affect the crop. Even after three decades of research a wholly satisfactory control for bacterial spot has not been developed. The disease flourishes during warm, windy, rainy periods. These conditions not only favor rapid spread and development of bacterial spot but they also interfere with applications of control measures at the time when they are most needed.

Until about the mid 1950's copper fungicides were the only materials available for control of bacterial spot. Copper fungicides are only of limited value for short periods. If bacterial spot was prevalent and weather conditions favored its rapid spread, copper fungicides often had no measurable effect on disease progress. In the late 1950's streptomycin and combinations of copper and streptomyin, showed much promise of providing good control of bacterial spot (1, 2). Within a short time, however, streptomycin-resistant strains of *X. vesicatoria* appeared (3, 4). From then on usefulness of streptomycin was limited to short periods or special circumstances.

In the mid 1960's combinations of copper and maneb or mancozeb were found to be considerably more effective than copper alone. Since then these combinations have been widely used in Florida for the control of bacterial spot. The combination of copper and maneb or mancozeb has been recommended by the Florida Cooperative Extension Service for many years. The experimental data supporting this recommendation and usage have never been published. To fill in this gap in the literature, we are presenting results of experiments with tomatoes performed in the 1950's and 1960's relating to the superiority of copper-ethylene bisdithiocarbamate (CEB) combinations for bacterial spot control. Also presented are data regarding their compatibility for control of late blight (*Phytophthora infestans* (Mont.) dBy.) and gray leaf spot (*Stemphylium solani* Weber).

Materials and Methods

All experiments were conducted at Agricultural Research and Education Center or at the Rohm & Haas Experimental Farm, Homestead during fall and winter months. Experiments on control of bacterial spot and gray leaf spot were performed in 1962-1964 and on late blight in 1956-57. Some experiments were performed on tomato plant beds, others were on plants grown to maturity. Insect pests were controlled by separate applications of insecticides. Sprinkler irrigation was used as needed to maintain optimum conditions for disease development.

A randomized complete block design was used in all experiments. Sprays were applied in most instances with a tractor-drawn power sprayer but, in some tests, applications were made by hand with a compressed air sprayer. Care was taken to insure complete coverage as possible on all leaf surfaces. In plantbed experiments sprays were applied at 3 to 4 day intervals until plants were 12″ to 15″ tall. In experiments where plants were grown to maturity applications were made at 3 to 7 day intervals until the end of the harvest. In most tests plants were inoculated with a culture of *X. vesicatoria* or with conidia of *S. solani.* Secondary spread of diseases was by natural means.

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Results and Discussion

Results presented in Tables 1, 2, 3 and 4 clearly show that combinations of BCS with maneb (Dithane M-22, Manzate) or mancozeb (Dithane M-45, Manzate 200) provided better control of bacterial spot than BCS alone with differences in 3 of 4 experiments being statistically significant. In 3 experiments mancozeb was superior to maneb when combined with BCS with differences being statistically significant in 2 instances. Of the other materials tested in combination with BCS, only du Pont 328, an experimental fungicide, improved on the performance of BCS. Combining captafol (Difolitan) or anilazene (Dyrene) with BCS did not improve bacterial spot control compared to BCS alone. Copper zinc chromate (Miller 658) was about as effective as BCS for bacterial spot control. Control was improved when it was combined with maneb or mancozeb but not to the same degree as when BCS was combined with these materials. These results indicate that enhancement of bacterial spot control is due to the interaction of specific materials and is not to be expected from combinations of any fungicides.

Table 1. Control of bacterial spot and gray leaf spot of tomatoes with maneb, mancozeb and combinations with BCS.

Fungicide and lbs/100 gals	Bacterial spot No. lesions on 25 seedlings 10/23/62	Gray leaf spot. No. lesions/20 leaflets 1/21/63	1/30/63
Maneb, 1.5	668 ab[z]	141 ab	142 ab
Maneb, 1.5 + BCS, 4	349 ab	173 b	243 b
Mancozeb, 1.5	493 ab	103 a	88 a
Mancozeb, 1.5 + BCS, 4	243 a	175 b	242 b
BCS, 4	717 b	TNC[y]	TNC

[z]Differences between numbers followed by the same letter are not statistically significant according to Duncan's Multiple Range Test.
[y]Too numerous to count. Not included in analyses.

Table 2. Control of bacterial spot in tomato plantbeds with certain fungicides alone and in combination with BCS.

Fungicide and lbs/100 gals	Bacterial spot ratings[z] 8/8/63[y]	9/14/63[x]	9/24/63[w]
Maneb, 1.5	4.1 bc	2.3 b	2.8 cd
Mancozeb, 1.5	4.1 bc	2.8 b	2.5 bc
Anilazene, 1.5	4.0 bc	4.5 c	3.0 cd
BCS, 4	3.9 bc	4.0 c	3.0 cd
Maneb, 1.5 + BCS, 4	2.8 ab	1.8 ab	1.3 a
Maneb, 1.5 + BCS, 4[v]	3.0 ab	2.3 b	1.8 ab
Mancozeb, 1.5 + BCS, 4	2.0 a	1.0 a	1.0 a
Anilazene, 1.5 + BCS, 4	4.3 bc	4.0 c	2.8 cd
Check	5.0 c	5.0 c	3.5 d

[z]Differences between rating followed by the same letter are not statistically significant according to Duncan's multiple range test.
[y]Rate on a 1-7 scale where 1 = no disease, 3 = few lesions on numerous leaves, 5 = moderately severe and 7 = severe.
[x]Rated on a 1-5 basis where 1 = best and 5 = worst plot in each replicate.
[w]Rated on a 1-5 basis where 1 = best plot in replicate and 5 = plants dead.
[v]Materials applied separately.

The same CEB combinations which enhance control of bacterial spot were less effective for control of gray leaf spot than the carbamate alone (Tables 1 and 5). It is interesting that the fungicidal effectiveness of mancozeb was reduced to a greater degree than maneb by the presence of copper, whereas mancozeb was generally more effective than maneb for control of bacterial spot. On the other hand, CEB

Table 3. Control of bacterial spot in tomato plantbeds with certain fungicides applied separately and combined with BCS or copper-zinc chromate (CZC).

Fungicide and lbs/100 gal	Bacterial spot ratings[z] Oct 15[y]	Oct 21[x]	Phytotoxicity
Mancozeb, 1.5 + BCS, 4	1.0 a	1.9 a	none
Du Pont 328, 2 + BCS, 4	2.0 ab	2.1 a	none
Mancozeb, 1.5 + CZC, 2	2.3 b	2.7 b	none
Du Pont 328, 2	2.8 b	2.8 b	none
Captafol, 2[w]	3.0 b	2.9 bc	moderate
Maneb, 1.5 + BCS, 4	2.3 b	2.9 bc	none
Captafol, 2[w] + BCS, 4	2.8 b	3.3 bcd	severe
CZC, 2	4.3 c	3.6 cd	none
BCS, 4	4.3 c	3.8 d	slight
None (check)	5.0 c	4.7 e	

[z]Differences between ratings followed by the same letter are not statistically significant according to Duncan's multiple range test.
[y]Rated on a 1-5 scale where 1 = best and 5 = worst plot in each replicate.
[x]Avg. ratings (by 3 individuals) of 25 plant samples from each plot (1 = best and 5 worst in each replicate).
[w]Amount reduced to 1 lb after first application because of phytoxicity.

Table 4. Control of bacterial spot in tomato plantbeds with BCS and copper-zinc chromate (CZC) in combinations with maneb and mancozeb.

Fungicide and lbs/100 gal	Bacterial spot ratings Rating A[z]	Rating B[y]
BCS, 4 + maneb, 1.5	2.4 a[x]	1.0 a
" " + maneb + $ZnSO_4$	2.7 ab	1.0 a
" " + mancozeb, 1.5	2.8 abc	1.0 a
" " + maneb, 1.5	2.8 abc	1.3 a
CZC, 2 + maneb, 1.5	3.3 cd	2.0 b
" " + maneb + $ZnSO_4$	3.1 bc	2.0 b
" " + mancozeb, 1.5	3.0 abc	2.0 b
" " + maneb, 1.5	3.3 cd	2.3 b
BCS, 4	4.1 e	3.3 c
None (check)	4.2 e	3.8 c

[z]Rating on 1-5 scale where 1 = few spots on bottom leaves, some epinasty, no abscission; 3 = occasional spots on upper leaves, numerous spots on middle leaves with some epinasty and yellowing, bottom leaves abscised; 5 = spots on most upper leaves, middle leaves very yellow or abscised, bottom leaves abscised.
[y]Rating on 1-5 scale where 1 = best and 5 worst plot in each replicate.
[x]Differences between ratings followed by the same letter are not statistically significant according to Duncan's multiple range test.

combinations gave better control of gray leaf spot than BCS alone. Similar evidence of the incompatibility of BCS and maneb as a fungicide was obtained from 2 experiments on control of late blight (Table 6). Compared to maneb alone, control was reduced whether BCS and maneb were combined or applied alternately, but control was improved compared to BCS alone. The question of incompatibility of CEB combinations is of concern since bacterial spot and fungus diseases may occur at the same time. Under mild conditions, reduced control of fungus diseases would be of little consequence, but with suitable environmental conditions, fungus diseases could develop to a damaging level.

Although CEB combinations are more effective than copper fungicides alone, and are the best available controls for bacterial spot, it should be emphasized that such combinations are not effective under all circumstances. In a general way CEB combinations are 2 to 3 times as effective as copper alone. They give fair to good control when inoculum is low, or when weather conditions do not favor rapid disease development, or when such periods are of short duration. But if environmental conditions favor disease de-

Table 5. Control of gray leaf spot of tomato with maneb and mancozeb alone and in combination with BCS.

Fungicide lbs/100 gal	Avg. no. lesions/leaflet[z] 1/13/64	1/24/64
Maneb, 1 + Anilazene, 1	1.6 a	2.6 a
Mancozeb, 1.5	3.8 ab	3.4 ab
Maneb + $ZnSO_4$	2.5 ab	3.9 bc
Maneb, 1.5	2.3 ab	4.1 bc
Maneb, 1.5 + BCS, 4	4.2 b	5.5 d
Mancozeb, 1.5 + BCS, 4	14.3 c	6.4 e
None (check)	30.2 d	—

[z]Differences between numbers followed by the same letter are not statistically significant according to Duncan's multiple range test.

velopment long enough, CEB combinations will be overwhelmed eventually.

Table 6. Control of late blight of tomato with fungicidal programs alternating or combining copper fungicides with maneb or zineb.

Fungicide lbs/100 gal	No. lesions/ 10 leaves	Total yield lbs/plot
1955-56 Experiment		
maneb, 1.5 alternated with zineb, 2	2.0	—
same but BCS 4 applied between each carbamate spray	11.0	—
None (check)	50.8	—
LSD @ 5% level	10.2	—
1956-57 Experiment		
maneb, 1.5 alternated with zineb, 2	7.0	127.2
BCS, 4	—	26.5
maneb, 1.5 + BCS, 4	22.0	68.4
None (check)	34.0	17.6
LSD @ 5% level	9.1	23.5
LSD @ 1% level	12.6	32.1

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FIFTY YEARS OF WATERMELON BREEDING AT ARC LEESBURG[1]

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Additional index words. Fusarium wilt, anthracnose, gummy stem blight, downy mildew, watermelon mosaic, intense red flesh color, Florida Seedling 124.

Abstract. **The Leesburg unit of the Florida Agricultural Experiment Stations was established by an act of the 1929 legislature primarily to study and devise controls for Fusarium wilt of watermelon. A breeding program was begun in 1931. This program, with emphasis on the improvement of melon quality and the selection of disease resistant types, has continued till now, but goals of the program were changed from time to time to meet the changing problems of the Florida watermelon industry. This paper traces the history of those changes and summarizes the accomplishments of the program.**

The Leesburg unit of the University of Florida's Agricultural Experiment Stations system was established in 1930 as a field laboratory for the study of disease and insect problems on watermelons. One of its primary goals was to devise controls for Fusarium wilt, which was causing major losses to Florida watermelon growers, particularly those in the important production area in the central part of the state. A tract of land was leased near Leesburg and 104 varieties were planted in 1930 on 10 acres that had been planted in watermelons 3 times in the previous 11 years. Most of these plants died from Fusarium wilt, but seed from the survivors were planted in 1931 and the first crosses were made on them that year. Emphasis in the early years of the program was on resistance to Fusarium wilt, and many crosses and selections were made with the object of developing new wilt-resistant varieties. One of the most fortuitous was a 'Hawkesbury WR' x 'Leesburg' cross made in 1936. Selections from this cross were made available to many watermelon breeders. One of them, designated Florida Seedling 124, has been recognized as the source of high-level resistance to wilt in 'Calhoun Gray', 'Summit', and 'Calhoun Sweet' (1, 12). Four other cultivars with high level resistance to wilt ('Smokylee', 'Verona', 'Whitehope', and Texas W5) also have 'Hawkesbury' and 'Leesburg' in their genealogy (8). In 1936 anthracnose-resistant breeding lines were acquired and incorporated into the breeding program (9, 13). Lines incorporating anthracnose and Fusarium wilt resistances in horticulturally desirable types were widely distributed to other breeders, so that Florida lines are found in the genealogy of many of the watermelon varieties currently grown in this country and throughout the world. From these beginnings, the watermelon program at Leesburg has continued to the present time, with additional goals being added from time to time. Important goals over the years have been the development of varieties producing high yields of early maturing melons with desirable eating and shipping qualities on vigorous vines with multiple disease resistance (including resistances to Fusarium wilt, anthracnose, downy mildew, watermelon mosaic, and gummy stem blight).

Breeders and Cultivars

The Florida breeding program was begun at Leesburg in 1930 under the guidance of Marion N. Walker. He resigned in 1945 to assume duties with the U.S. Department

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