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A STUDY OF THE EFFECTS OF COPPER SPRAY MATERIALS ON PRODUCTION, GRADES, AND DISEASE CONTROL OF TOMATOES

by

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A THESIS

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Introduction

The protection of tomato foliage from the attacks of leaf spots (*Septoria lycopersici* and *Alternaria solani*) by the application of sprays is becoming necessary in Michigan because of the losses which threaten the crop each year. Statistics* show that the injury done to Michigan's 9,500 acres of tomatoes by these leaf spot diseases during the years from 1928 to 1938, inclusive, with the exception of 1929, was 575,592 bushels, with an approximate value of $283,747. The average annual loss for this period was $28,337. The average annual loss for the last four years, 1935 to 1938, was 75,127 bushels with an approximate value of $68,000. This loss is a challenge to the Michigan Tomato growers. Can it be profitably checked? The most commonly recommended spray up to this time is Bordeaux mixture. Various low-soluble copper compounds have been placed on the market and are recommended by certain manufactures for the control of tomato diseases.

The purpose of this investigation was to study the effects of the various copper compounds on production, grades, and disease control of tomatoes.

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*Michigan Crop Report for 1938 and Plant Disease Reporter, Supplements 83, 87, 89, 94, 100, and 108.

Review of Literature

Schneiderhan of Virginia (18) in giving the early history of the copper spray materials states that the fungicidal properties of the copper compounds were discovered by Prevost in 1807. Millardet of France discovered Bordeaux mixture in 1882. One of his first formulae was as follows: 18 lbs. copper sulfate, 33 lbs. stone lime, and 34 gallons of water, which was applied with a brush. In 1887 Bordeaux mixture was introduced into the United States, and the first formulae recommended were 8-10-20, 16-30-29, and later 6-2-22. Bedford and Pickering (1) discuss the soluble and insoluble copper compounds, showing the chemical reactions and their effects on the fungus diseases.

Coons and Levin of Michigan (4), also Bessey (2) of the Michigan Agr. Exp. Sta. mention Septoria leaf spot of tomato as being a serious disease causing much damage in Michigan.

Sherbakoff of Florida (19) spoke of late blight and leaf spot as being two destructive diseases and recommended a 4-4-50 Bordeaux mixture to be applied every ten days. Humbert (10) recommended to the growers in Ohio a 4-4-50 Bordeaux mixture, not as a cure for leaf spots but as a preventive. Kadow and Shropshire of Illinois (12), Strong of Michigan (23), Rolfs of Florida (17), and Ramsey and Link of the U. S. D. A. (16), all recognize Bordeaux mixture as the best control for Septoria and Alternaria leaf spots.

In Pennsylvania, Muncie (13) obtained his best control of Septoria leaf spot with Bordeaux mixture plus a fish oil soap as a sticker, but this material did not increase the yield above that of the check.

Wilson and Runnels (26) in their 5 years of experiments in Ohio found that Bordeaux mixture decreased the yield of tomatoes to below that of the untreated plants during 4 of the 5 years. These investigators (24) (25) also found that Bordeaux mixture retarded the growth of the plant and increased transpiration. Shrive and Martin (20) found that Bordeaux mixture increased transpiration as much as 29 per cent during the middle of the day. Pritchard and Porte of U. S. D. A. (15) reported a gain from Bordeaux mixture in experiments run in 4 different states. Muncie and KenKnight (14) in their Michigan trials used Bordeaux mixture in comparison with some of the new copper compounds and found that plots sprayed with the Bordeaux mixture yielded less. Horsfall, Magie, and Suit of New York (8) found that Cuprocide 54 (85 per cent red copper oxide) was less detrimental to young plants and blossoms than Bordeaux mixture. The plants sprayed with these materials gave an increased yield. In their experiments they found that transpiration was accelerated by the use of Bordeaux mixture and that it increased blossom end rot.

Edgerton's (6) work in Louisiana showed that spraying with Bordeaux mixture controlled Alternaria leaf spot of tomato very satisfactorily, but caused a delay in the ripening of the fruit. Fromme's (7) experiments in Virginia showed that Bordeaux mixture-sprayed plots gave a marked increase in yield of sound ripe fruits over the check when defoliation was serious.

Horsfall and Magie (8) found in their experiments that fruits ripen as soon on Bordeaux-sprayed plants as on unsprayed plants and believe that the injury done to the open blossoms at spraying time is the cause

of delayed ripening.

Smith and Cochran of New York (22), showed that temperature greatly influences the germination of pollen grains and the growth of the tubes, the optimum temperature being about 80° F.

The studies made by Duggar (5) showed that the red pigments in the tomato did not develop at temperatures above 85° F. Smith of New York (21), and Jones and Rosa (11) all agree that tomato fruits will develop in light or darkness and that red color begins to develop at 50° F. and continues up to 85° F. Butler (3) found that the leaves of the plant sprayed with Bordeaux mixture cooled less rapidly, and therefore prolonged the period of ripening.

Materials and Methods

Nine copper containing materials were chosen for this study. These materials were used on a basis of 25 per cent copper, with the exception of Oxo-Bordeaux*. The materials chosen and the amount used per 50 gallons of water are as follows:

1. Basi-cop . . . . . 2 lb. to 50 Gal. water
2. Bordow . . . . . 4 lb. " " " "
3. Coposil . . . . . 4 lb. " " " "
4. Cuprocide 54 . . . . . 1 1/3 lb. " " " "
5. Bordeaux 4-2-50 . . . . . 4-2 lb. " " " "
6. Copper-oxychloride A . . . . . 2 lb. " " " "
** 7. Oxo-Bordeaux . . . . . 2 2/3 lb. " " " "
8. Check . . . . . .
9. Bordeaux 4-6-50 . . . . . 4-6 lb. " " " "
***10. Cupro-K . . . . . 3 lb. " " " "

All plots, including checks, were sprayed with calcium arsenate at the rate of 3 pounds per 100 gallons to protect the plants from the tomato worm.

Home grown John Baer plants were used in all the plots. The John Baer variety of tomato was selected because it was more susceptible to Alternaria solani and Septoria lycopersici than some other varieties.

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*Oxo-Bordeaux was used according to the manufacturer's recommendation.
**8 lbs. to 50 gallons of water was used in 1939.
***Not used in 1939.

The plants were started in the greenhouse and at the age of 3 weeks were transplanted into $3\frac{1}{2}x3\frac{1}{2}x4\frac{1}{2}$ inch wood veneer bands. About the time the first buds appeared the plants were hardened slightly and made ready for field transplanting.

The soil in the field chosen for the plants was comparatively uniform. In 1938 the field was laid off into 30 plots, making 3 plots for each material and the check, while in 1939 the field was laid off into 36 plots, making 4 plots for each material and the check. Ample space was left between plots so there would be no drift of materials during spraying. The rows were marked off with the potato planter, which applied commercial fertilizer at the rate of 500 pounds per acre or approximately 3 ounces per plant.

Although the plan was to spray every week until picking time, unfavorable weather interfered in some cases. The spray applications in 1938 were given on the following dates: June 13, June 24, July 7, July 15, July 29, and August 9. The plants were thoroughly covered with each application, using an average of about 350 gallons of spray material per acre. A fine mist was produced by using 400 lbs. pressure with the No. 4 disk in the spray gun.

Provisions were made to irrigate by the overhead method if it should be necessary. Water was added during both years to maintain the normal growth of the plants.

The fruits were harvested once each week beginning August 4 in 1938 and August 10 in 1939.

Two defoliation counts were taken during the 1938 season and 3 during 1939.

The per cent set of the first 3 blossom clusters was calculated from the clusters tagged. A cluster was also tagged later in the season and the per cent set was calculated and recorded for this cluster.

In order to determine the amount of injury to the open blossoms at the time of spraying, individual open blossoms were tagged immediately after the spray applications. The records of set were taken 15 days after the clusters were tagged.

In 1939 2 methods of spraying were followed. The comparisons of the 2 methods of spraying were as follows: (1) spraying throughout the season, and (2) spraying after disease appeared. This comparison was made by dividing the 4 replications of each plot into 2 groups. The group sprayed throughout the season will be designated as the A plots throughout this thesis and the group sprayed after disease appeared as the B plots.

There were signs of Alternaria leaf spot on the B plots by July 24. At this date they were sprayed for the first time. All (A and B) plots were given 3 more applications, making 7 for the A plots and 4 for the B plots.

Presentation of 1938 Data

Effects on Yield

The production records are given in Table I. All plots showed an increased yield above the check with the exception of Copper oxy-chloride, Bordeaux 4-6-50, Bordeaux 4-2-50, and Cupro-K. The Coposil plot ranked first in yield with Basi-cop, Cuprocide, Oxo-Bordeaux, and Bordow, following, respectively. The gain over the check for the Coposil plot was only 1.7 tons per acre. The other materials exceeding the check showed less increase per acre than Coposil. Its gain was very small and it was doubtful whether the increased yield was significant. It was interesting to note that the check plot produced the greatest number of ripe fruits. The 4 materials that ranked next to the check in number of ripe fruits were Basi-cop, Coposil, Oxo-Bordeaux, and Cuprocide. The 3 plots which produced the least number of fruits were Cupro-K, Bordeaux 4-6-50, and Bordeaux 4-2-50. The weight of the individual fruits did not correspond with the number of fruits harvested. The check plot produced 2,778 ripe fruits with an average weight of 4 oz. This plot exceeded all plots in the number of ripe fruits produced, but the average weight of the fruits was the least. Bordeaux 4-2-50 produced the least number of fruits, (1,945) but their individual weights ranked highest (5.16 oz.). It is interesting to note that as the number of fruits increased, the average weight decreased.

When the U. S. No. 1 canning fruits were graded out and their total weights recorded the following plots ranked below the check: Copper-oxy-chloride, Bordeaux 4-2-50, Bordeaux 4-6-50, and Cupro-K.

Table I - 1938 Yield Records of Tomato Plots Sprayed with Various Copper Compounds and of the Unsprayed Checks

	Total lbs. Harvested	Total No. Fruits Harvested	Ounces Per Fruit	Pounds No. 1 Canning Fruit	Pounds No. 2 Canning Fruit	Pounds of Culls	Tons Per Acre Harvested
Basi-cop	746.0	2663	4.40	628	47	71	20.7
Bordow	710.0	2292	4.91	605	45	59	19.6
Coposil	760.5	2442	4.98	608	47	105	21.0
Cuprocide	738.5	2298	5.10	611	50	77	20.5
Bordeaux 4-2-50	628.0	1945	5.16	481	62	85	17.4
Copper-oxychloride	659.5	2208	4.77	557	33	69	18.3
Oxo-Bordeaux	729.5	2305	5.06	606	40	83	20.2
Check	695.5	2778	4.00	573	29	93	19.3
Bordeaux 4-6-50	630.5	2151	4.68	476	58	99	17.5
Cupro-K	574.5	2115	4.34	462	37	74	15.9

The plots which ranked above the check in pounds of U. S. No. 1 were Basi-cop, Cuprocide, Coposil, Oxo-Bordeaux and Bordow. The U. S. No. 2 canning fruits were few. Those plots which graded low in pounds of U. S. No 2 graded high in pounds of culls. The check plot graded out the least in pounds of U. S. No. 2, but the culls ranked third highest. Bordeaux 4-2-50 ranked first in pounds of U. S. No. 2, and fourth in culls, while the Bordeaux 4-6-50 ranked second in both pounds of U. S. No. 2 and culls.

Effect on Maturity

At the end of the season the plots were picked clean. By so doing each plot received credit for the total number and pounds of fruit found on the vines at that time. These records were kept separately for the purpose of making some comparisons of late maturity. After these were completed, they were added to the previous records making the grand total number of fruits and the grand total pounds of fruit for each plot. These data are recorded in Table II.

The total number of fruits gathered from the plots at cleanup time varied greatly. There were only 29 fruits gathered from the check plot, while others varied from 74 to 1,950 fruits.

There were 5 plots which produced a large number of immature fruits. They are listed in the order of their production, Bordeaux 4-2-50, Bordow, Copper oxychloride, Cuprocide, and Bordeaux 4-6-50. These 5 plots with the exception of Cupro-K. ranked the lowest in number of fruits during the picking season when marketable fruits were harvested.

Table II - Records of the Number and Pounds of Tomatoes Harvested at the End of the Season, also the Grant Total Number and Grand Total Fruits for the Entire 1938 Season.

	Total Fruits at Clean-up	Total Pounds at Clean-up	Grand Total Fruits at Clean-up	Grand Total Pounds at Clean-up
Basi-cop	356	29.0	3019	775.5
Bordow	1822	159.5	4114	869.5
Coposil	944	78.5	3386	839.0
Cuprocide	1275	120.0	3573	858.5
Bordeaux 4-2-50	1950	190.0	3895	818.0
Copper-Oxychloride	1332	123.0	3540	782.5
Oxo-Bordeaux	875	70.0	3180	799.5
Check	29	2.5	2807	698.5
Bordeaux 4-6-50	1116	92.0	3267	722.5
Cupro-K.	74	5.5	2189	579.0

When the number of fruits gathered at cleanup time was added to the number of ripe fruits gathered at harvest time, it was found that the check ranked next to the lowest. The plot which ranked the lowest was Cupro-K. The plots ranking high were Bordow, Bordeaux 4-2-50, Cuprocide and Copper-oxychloride. The Bordow plot ranked first in grand total pounds and also ranked first in Grand total number of fruits. Cupro-K and the check which ranked lowest in grand total pounds also ranked lowest in grand total fruits.

Effect on Fruit Setting

The per cent of set on the first 3 clusters as well as that on one cluster later in the season is recorded in Table III. The check plot gave the highest per cent of set, with Cupro K, Cuprocide, Basi-cop, Oxo-Bordeaux, and Bordeaux 4-2-50 following.

The greatest per cent of set on the cluster tagged July 19 was found on the Basi-cop plot.

Effect on Defoliation

Two counts to show defoliation from leaf spot diseases were made during the season; the first on August 7, and the second on September 18. The percentage of defoliation for each plot is given in Table IV. The check was most heavily defoliated on August 7. The least defoliated plot at that date was Bordeaux 4-2-50, with Bordow, Bordeaus 4-6-50, and Copper-oxychloride following in the order named. The plot showing least defoliation on September 18 was Bordeaux 4-2-50, followed by Basi-cop, Cuprocide, Bordeaux 4-6-50, and Bordow.

Table III - The Per cent Set on the First Three Clusters and on a Single Cluster Tagged July 19, 1938

	Per cent Set on First Three Clusters	Per cent Set on Cluster Tagged July 19
Basi-cop	61.3	46.4
Bordow	57.3	28.2
Coposil	54.2	24.4
Cuprocide	62.0	30.0
Bordeaux 4-2-50	61.1	32.5
Copper-oxychloride	60.8	18.6
Oxo-Bordeaux	61.2	35.4
Check	69.4	29.3
Bordeaux 4-6-50	52.8	32.3
Cupro-K	65.2	24.7

Table IV - Per cent of Leaves Lost from Effects of Septoria and Alternaria Leaf Spots on Sprayed and Unsprayed Plots during 1938

	Per Cent of Leaves Lost	
	August 7	September 18
Basi-cop	74.2	90.1
Bordow	33.1	92.6
Coposil	65.0	94.8
Cuprocide	43.9	91.2
Bordeaux 4-2-50	19.3	87.4
Copper-oxychloride	41.0	95.3
Oxo-Bordeaux	62.1	93.6
Check	90.0	95.1
Bordeaux 4-6-50	40.0	92.1
Cupro-K	87.3	96.3

Effect on Blossom Set

For the purpose of detecting spray injury to the open blossoms 3 open blossom clusters on each plot were tagged immediately after the spray applications on August 15 and August 29. When the count was made on August 15, Basi-cop ranked the highest in set with the check and Cuprocide following, being equal. The plots which showed a set below the check were Cupro-K, Oxo-Bordeaux, Coposil, Bordeaux 4-2-50, and Bordeaux 4-6-50. Table V.

Effects on Peak of Production

From the picking records the peak production week was determined. It was found that all plots reached their peak of production on August 23 with the exception of Bordeaux 4-2-50 and Bordeaux 4-6-50, which reached their peak of production 13 days later (September 5).

The Value of Spraying

Table VI shows the relative value of spraying. It may be well to state the conditions under which these yields were produced. The plants made a heavy growth early in the season. Leaf diseases made their appearance rather late and the dry weather during the last part of July was not favorable for the spread of Septoria and Alternaria. The damage from the leaf spots which came during late July did not influence the yield of the check as it did in 1939.

It was stated previously that gains in yeild were shown above the check by 6 plots. These gains may not represent a profit as compared

Table V - The Per cent of Individually Tagged Blossoms Which Developed after being Covered with Spray Materials on August 15

	Blossoms Selling Fruit (per cent)
	August 15
Basi-cop	77
Bordow	--
Coposil	22
Cuprocide	44
Bordeaux 4-2-50	22
Copper-oxychloride	--
Oxo-Bordeaux	22
Check	44
Bordeaux 4-6-50	33
Cupro-K	22

Table VI - The Value of Spraying as Shown by Increased Yield Over Check and Cost of Spraying Per Acre for Six Applications in 1938

	Increased Yield over check (Tons per Acre)	* Estimated Value of Increased Yield	** Estimated Cost of Spraying	Profit or Loss from Spraying
Basi-cop	1.4	$22.40	$24.12	$-1.72
Bordow	.3	4.80	42.60	-37.80
Coposil	1.7	27.20	37.08	-9.88
Cuprocide	1.2	19.20	32.62	-13.42
Bordeaux 4-2-50	-1.9	-30.40	20.52	-50.92
Copper-oxychloride	1.0	16.00	24.12	-8.12
Oxo-Bordeaux	.9	14.40	46.16	-30.76
Check	- -	- -	- -	- -
Bordeaux 4-6-50	-2.0	-32.00	21.96	-53.96
Cupro-K	-3.4	-54.40	36.36	-90.70

* Figured on the basis of canning tomatoes, $16.00 per ton.

** Material and labor for six applications. The estimated labor costs per application as taken from the commercial sprayed field was $1.85 per acre, or $11.10 for six applications.

with the check. Table VI is set up to show the increased yield over the check and its value.

Three plots produced less than the check: the Cupro-K, Bordeaux 4-2-50. The losses per acre which occurred from spraying these plots were as follows: Cupro-K, $90.70; Bordeaux 4-6-50, $53.96; and Bordeaux 4-2-50, $50.90.

The plots: Basi-cop, Coposil, Cuprocide, Copper-oxychloride, and Bordow all showed a slightly increased yield over the check. The value of these increases at the canning price of tomatoes, $16.00 per ton, did not pay for the cost of spray materials used. The Basi-cop plot with an increase over the check of 1.4 tons per acre showed a money loss after the cost of the 6 spray applications was deducted. In other words, it would have been $1.72 more profitable if no spray applications had been made. All other plots also showed a loss.

Presentation of 1939 Data

This experiment was continued during 1939 for the purpose of studying the effects of these spray materials on tomato production, grades and leaf spot control when applied (1) throughout the season, (7 applications), and (2) after leaf spot becomes apparent (4 applications). The data compiled are given in Tables VII to XI.

Effect on Yield

The yields in tons per acre for the different materials are recorded in Table VII. The A plots were sprayed throughout the season while the spray program began on the B plots at the first appearance of blight about July 24, and continued until the end of the season. The following A plots (7 applications) showed an increase in yield over the B plots (4 applications): Basi-cop, Bordow, Coposil, Cuprocide, Bordeaux 4-2-50, Copper-oxychloride, and Oxo-Bordeaux. The A plots showing a marked increase in yield over those of the B plots are Cuprocide 54, with an increase of 4.8 tons per acre, Bordow with 2.9 tons per acre, and Bordeaux 4-2-50 with an increase of 2 tons per acre. Bordeaux 4-6-50 showed no significant difference. When the materials in both A and B plots are compared with the unsprayed check we find all exceed it in yield.

Table VII - 1939 Yields in Tons per Acre of Marketable Fruit from Plots Sprayed Throughout Season and Plots Sprayed only During Late Season

	*A Plots	**B Plots
Basi-cop	19.1	18.4
Bordow	25.3	22.4
Coposil	20.7	20.2
Cuprocide 54	26.0	21.2
Bordeaux 4-2-50	24.6	22.6
Copper-oxychloride	22.5	21.2
Oxo-Bordeaux	21.6	20.5
Check	13.8	13.5
Bordeaux 4-6-50	22.2	22.3

*A Plots sprayed throughout season: June 18, June 27, July 9, July 24, August 3, August 18, August 30.

**B Plots sprayed in late season only: July 24, August 3, August 18, August 30.

Effect on Fruit Setting

Three groups of open blossoms were tagged on June 29, July 9, and August 3, immediately after the spray applications. All B plots tagged on June 29 and July 9 can be considered with the checks as no spray materials were applied to them until July 24. In most cases the per cent of set was less on the A plots than it was on the B plots.

Due to the fact that only 40 blossoms were tagged, the setting records are too variable and inconsistent to warrant drawing any conclusions as to the influence of any of the treatments on the process of fruit setting.

Table VIII - Effect of Spray Materials on Per Cent of Blossoms Set in 1939

	June 29		July 9		August 3	
	*A Plots	**B Plots	*A Plots	**B Plots	*A Plots	**B Plots
Basi-cop	35	60	55	90	32.5	25.0
Bordow	45	55	70	60	30.0	42.5
Coposil	40	45	35	60	35.0	35.0
Cuprocide	70	60	85	80	42.5	32.5
Bordeaux 4-2-50	30	70	70	80	30.0	25.0
Copper-oxychloride	40	65	80	65	32.5	30.0
Oxo-Bordeaux	45	45	55	70	22.5	30.0
Check	75	55	80	75	32.5	32.5
Bordeaux 4-6-50	45	70	45	80	35.0	12.5

*A Plots sprayed throughout season: June 18, June 27, July 9, July 24, August 3, August 18, August 30.

**B Plots sprayed in late season only: July 24, August 3, August 18, August 30.

Effect of Spray Materials on Defoliation

The percentage of leaves lost as a result of leaf spot infection on sprayed and unsprayed plants is given in Table IX. The defoliation counts were taken on the following dates: July 15, August 15, and September 15.

The B plots received no sprays until after the first defoliation count was taken on July 15. Observations were made at this date and no difference could be detected between any of the A and B plots. The A plots had received 3 spray applications by July 24 and the same percentage of defoliation for both A and B plots is recorded for the following: Basi-cop, Copper-oxychloride, and the check. The other materials showed slight variations.

One month later, on August 15, the second count was made which showed a much higher per cent of defoliation. The check plot showed 10 per cent more defoliation than any other A plot.

The A plots showing least defoliation on August 15 were Bordow, Bordeaux 4-2-50, Cuprocide, Copper-oxychloride, and Bordeaux 4-6-50, respectively. The loss of leaves on all B plots where applications of identical materials were made was greater, at this date than on the A plots with the exception of the Basi-cop which was equal, and Coposil which showed 10 per cent less defoliation on the B plot. This one instance might not be significant but all the A plots for Coposil throughout the season show a greater defoliation than the B plots which indicates no additional protection from the early spray applications.

The final defoliation count was made on September 15. The most heavily defoliated plot was the unsprayed check. In general the

Table IX - Percentage of Leaves Lost from Effects of *Septoria* and *Alternaria* Leaf Spots on Sprayed and Unsprayed Plots at Various Dates During 1939

	July 15		August 15		September 15	
	*A Plots	**B Plots	*A Plots	**B Plots	*A Plots	**B Plots
Basi-cop	6	6	40	40	69	67
Bordow	3	6	29	48	60	78
Coposil	5	3	41	31	70	67
Cuprocide	6	7	31	36	65	58
Bordeaux 4-2-50	5	4	29	32	43	46
Copper-oxychloride	6	6	33	39	73	62
Oxo-Bordeaux	4	6	39	44	53	53
Check	6	6	51	47	85	83
Bordeaux 4-6-50	5	7	32	38	62	51

*A Plots sprayed throughout season: June 18, June 27, July 9, July 24, August 3, August 18, August 30.

**B Plots sprayed in late season only: July 24, August 3, August 18, August 30.

defoliation was somewhat greater in the B plots than in the A plots. This small difference in defoliation may be attributed to (1) the use of disease free plants, and (2) the first application of the late spray being made on the B plots before infection became well established.

On September 4, 11 days after the last defoliation count, the pictures shown in Figures 1 to 9 were taken on the A plots. There are 2 views of each plot, one taken close-up, about 5 feet, and the other taken at a distance of about 20 feet. By observing these pictures the 5 materials which gave best protection from leaf spots are readily discerned.

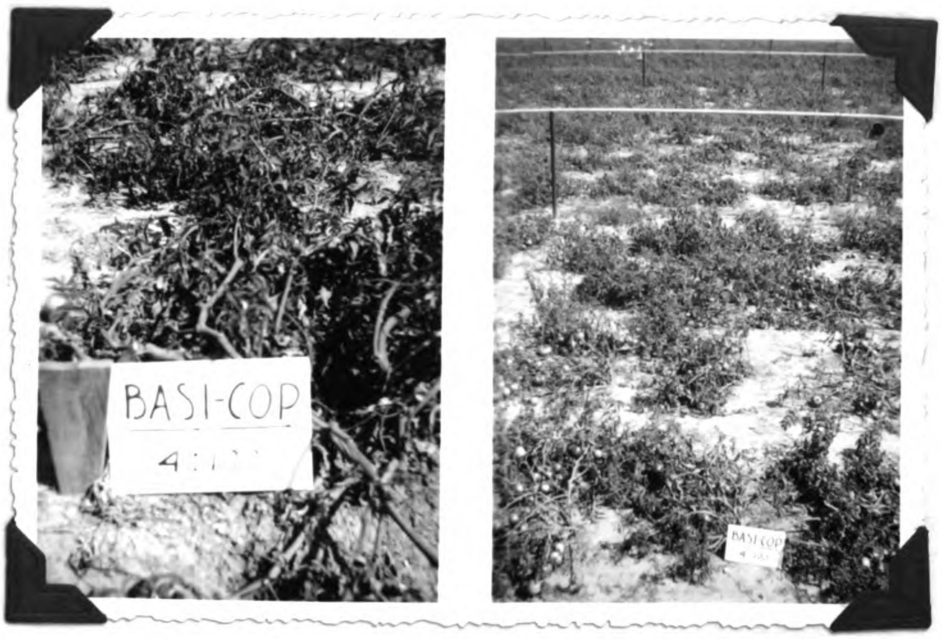

Fig. I. Sprayed with Basi-cop 4:100

Fig. 2. Sprayed with Bordow 16:100

Fig. 3. Sprayed with Coposil 8:100

Fig. 4. Sprayed with Cuprocide 54 - 2 2/3:100

Fig. 5. Sprayed with Bordeaux 8-4-100

Fig. 6. Sprayed with Copper-oxychloride A 4:100

Fig. 7. Sprayed with Oxo-Bordeaux 16:100

Fig. 8. The Unsprayed Check

Fig. 9. Sprayed with Bordeaux 8-12-100

The Effect on Peak of Production

The peak production dates as taken from the picking records were as follows: among the A plots there are 4 materials which showed a delay of 9 days in reaching their peak of production. These materials are Bordow, Cuprocide, Bordeaux 4-2-50, and Bordeaux 4-6-50. In the B plots the only material delaying peak harvest was Bordeaux 4-6-50.

Effect on Grade

Table X gives yield in pounds of marketable and unmarketable fruits from the A and B plots. The 3 A plots ranking highest in pounds of marketable fruit were Cuprocide, Bordow, and Bordeaux 4-2-50. Among the B plots the 3 materials ranking highest were Bordeaux 4-2-50, Bordow, and Bordeaux 4-6-50. It is interesting to note that both Bordow and Bordeaux 4-2-50 are among the 3 leading materials in both A and B plots.

The A plots having a high percentage of marketable fruits are Bordow, Cuprocide, Bordeaux 4-6-50, Oxo-Bordeaux, and Bordeaux 4-2-50. Bordow produced next to the greatest number of pounds with the highest percentage of marketable fruit. In every case the check yielded less fruit than any other plot.

Table X - Total Yields per Plot of Marketable and Unmarketable Fruits from Plots Sprayed with Various Copper Materials in 1939

	Marketable Fruit (pounds)	Unmarketable Fruit (pounds)	Total Yield (pounds)	Marketable Fruit (per cent)	Increase or Decrease over Check (pounds)
*A Plots					
Basi-cop	394.5	174.0	568.5	70	97.8
Bordow	523.7	152.0	675.7	78	205.0
Coposil	429.5	201.8	631.3	68	160.6
Cuprocide 54	537.4	172.5	709.9	73	239.2
Bordeaux 4-2-50	509.8	172.5	682.3	75	211.6
Copper-oxychloride	466.2	164.5	630.7	74	160.0
Oxo-Bordeaux	452.2	171.2	623.4	73	152.7
Check	286.2	184.5	470.7	68	- - -
Bordeaux 4-6-50	460.5	153.5	614.0	75	143.3
**B Plots					
Basi-cop	380.7	154.0	534.7	71	103.5
Bordow	463.6	155.0	618.6	75	187.4
Coposil	418.7	170.7	589.4	70	158.2
Cuprocide	438.2	143.6	581.8	75	150.6
Bordeaux 4-2-50	467.2	155.8	623.0	74	191.8
Copper-oxychloride	438.6	168.5	607.1	72	175.9
Oxo-Bordeaux	425.0	120.0	545.0	78	113.8
Check	280.6	150.6	431.2	65	- - -
Bordeaux 4-6-50	461.6	143.5	605.1	76	173.9

*Sprayed 7 times
**Sprayed 4 times

The Value of Spraying

Table XI shows the value of both early and late applications of spray materials. This table was set up in the following way: the increased yield in tons, over the check, the estimated value of this increase at the canning price of tomatoes, ($16.00 per ton), the estimated cost of spraying per acre, and the profit or loss as the case might be. All the figures in Table XI deal with the increased yield of tomatoes on the sprayed plots over the check, or unsprayed plots. Where there was a significant gain it was credited to the spray materials.

In this table are given the results for both A and B plots. The A plots received 7 applications of spray materials and the B plots received only 4. All A plots showed a gain in production over the check. Five plots showed a gain in yield over the check plot, which amounted to more than $100.00 per acre. These plots were Cuprocide, Bordeaux 4-2-50, Bordow, Copper-oxychloride, and Bordeaux 4-6-50. The Cuprocide plot was the outstanding one with a gain of $161.81 over the check. It is interesting to note that the gain from the high-lime Bordeaux was $40.08 less than that from the low-lime Bordeaux. Both Bordeaux mixtures gave good control of Alternaria and Septoria leaf spots, but other factors caused a lower yield.

When the plots were sprayed only 4 times, as they were in the B plots, there were 5 materials which showed more than $100.00 gain per acre over the check. These materials were the same 5 materials which showed the gain in the A plots.

Table XI - Value of Spraying as Shown by Increased Yield Over Check and Cost of Spraying Per Acre

	Increased Yield over Check (tons)	* Estimated Value of Increased Yield	** Estimated Cost of Spraying	Profit or Loss from Spraying
***A Plots				
Basi-cop	5.3	$ 84.80	$28.14	$ 56.66
Bordow	11.5	184.80	49.70	134.30
Coposil	6.9	110.40	43.26	67.14
Cuprocide 54	12.2	195.20	33.39	161.81
Bordeaux 4-2-50	10.8	172.80	23.94	148.86
Copper-oxychloride	8.7	139.20	28.14	111.06
Oxo-Bordeaux	8.0	128.00	55.02	72.98
Check	- -	- -	- -	- -
Bordeaux 4-6-50	8.4	134.40	25.62	108.78
****B Plots				
Vasi-cop	4.9	78.40	16.08	62.32
Bordow	8.9	142.40	28.40	114.00
Coposil	6.7	107.20	24.72	82.48
Cuprocide 54	7.7	123.20	19.08	104.12
Bordeaux 4-2-50	9.1	145.60	13.68	131.92
Copper-oxychloride	7.7	123.20	16.08	107.12
Oxo-Bordeaux	7.0	112.00	31.40	80.56
Check	- -	- -	- -	- -
Bordeaux 4-6-50	8.8	140.80	14.64	126.64

*The average canning price, $16.00 per ton.
**Cost of materials plus labor of applying.
***Seven applications.
****Four applications.

All the plots, both A and B, showed a net profit over the check plots. When the profits from the A and B plots were compared, it was found that some plots showed greater net profits when sprayed only 4 times, than plots sprayed 7 times with the same material. The plots showing outstanding net profits when sprayed only 4 times were: Bordow, Copper-oxychloride, Bordeaux 4-2-50, Cuprocide, and Bordeaux 4-6-50. The plots which showed similar net profits above the check when sprayed throughout the season (7 times) were: Cuprocide, Bordow, Bordeaux 4-2-50, and Copper-oxychloride. Of all plots (both A and B), the A plot sprayed 7 times with Cuprocide gave the greatest net profit of $161.81 per acre above the check plot.

Discussion

The Bordeaux mixture is the most commonly recommended and used material for the control of tomato leaf spots, but it has not been entirely satisfactory in every respect. The early recommendations were for the high-lime Bordeaux mixtures, but the tendency during recent years is toward the use of the low-lime Bordeaux mixtures.

From this study it appears advisable to use less lime than copper in the Bordeaux spray. The Bordeaux 4-2-50 gave good control of *Septoria* and *Alternaria* leaf spots and caused no copper injury.

Experiments (27), (26), and (8) show that Bordeaux mixtures increase transpiration which usually results in yields below those of the unsprayed plots.

In some sections of the South where the seasons are long and disease is severe, it is quite common to get an increase above the check with Bordeaux mixtures. These data for 1939 show that all Bordeaux-sprayed plots exceeded the checks in yield. It can readily be seen how this came about when the conditions are explained. The greatest retarding effect of the Bordeaux is due to the lime (26), causing heavy transpiration. If the excess lime is washed off by rain the retarding effect will be less. The first application was given to the plots on June 18 and the next day .47 inch of rain fell which removed some of the spray material. The evening following the spray application of June 27, .62 inch of rain fell. The spray application of July 24 was followed the next day by .85 inch of rain. The spray materials served as a protection during the rains, as this is the time

when infection is spread and a portion of the spray material was removed, which decreased the injury that would have followed had it remained.

During the early growing season of June 1939, the rainfall was 1.05 inch greater than in June, 1938. Throughout this period the plants made rapid growth and it was very difficult to keep them covered with spray material even though they were sprayed once each week. Experiments (8) show that the blossom bud development is in proportion to the dry matter in the plant. These plants had made a large growth and set much fruit before they received any injurious effects from the Bordeaux sprays. During the latter part of the season when disease was raging the plants were protected. The wet weather early in the season was ideal for the spread of leaf spots which caused much damage to the check plots and resulted in low yields. Under these conditions Bordeaux mixtures gave increased yields over the check plots. The question is continually coming before the growers, "When shall we spray the tomatoes or shall we spray at all?" There has always been a doubt as to whether the increased yield of the sprayed plants over the unsprayed plants would balance the cost of spray materials and the labor of application. When the grower is convinced that he should spray, he asks the question, "When shall applications be made?"

The data which are given in Table XI may help to answer these questions. The 1939 season was favorable for Septoria and Alternaria leaf spots. These diseases appeared early and spread rapidly throughout the remainder of the season. Every material used was given a true test and the results are easily read in Table XI. The check

was heavily defoliated early in the season which caused a low yield of poor quality fruit. This being true the protected plots, which produced over a longer period of time were given an opportunity to outyield the check. This was true in every plot, all increases being enough to be profitable.

The per cent of marketable fruit from the check plot was below that of any other plot and the quality of this marketable fruit did not equal that of the sprayed plots.

From the 1939 data 7 applications of Cuprocide would be considered the most profitable copper compound to use as a tomato spray. The low-lime Bordeaux (4-2-50), is the preferred Bordeaux mixture and is more profitable to use as an all season spray than the 4-6-50 Bordeaux. It is also more profitable than other materials when used only late in the season.

The safety of delayed spraying depends entirely upon the individual and the season. It is difficult to set a definite date on which to start the late spraying because disease does not make its appearance at the same time each year. The appearance of leaf spots and the severity of the attack is dependent upon the weather conditions. If the grower acquaints himself with the habits and life cycles of these diseases he may profitably delay his spray program until the first appearance of blight. If the grower is not so acquainted with these diseases he may suffer heavy loss by delayed spraying. Many of the plants imported from the South for canning stock have been found to carry leaf spot diseases. To those who use such plants it would be disastrous to delay spraying. After discussing delayed spraying from

these various standpoints, it would be safe to say, that it could be recommended to those who are acquainted with the habits of leaf spot diseases, providing they use disease free plants.

Summary

The results of two years spraying test with various copper fungicides on tomatoes for the control of Septoria lycopersici and Alternaria solani are reported.

Marked differences in the response from the various materials are shown between the 1938 and 1939 seasons.

In 1938 the leaf diseases did not appear until late in the season and none of the materials tested gave significant increases in yield over the unsprayed check plot.

In 1939 infection from Septoria lycopersici and Alternaria solani appeared early and continued throughout the season. This resulted in a heavy defoliation on the check plots before a large number of fruits could set.

The unsprayed check plots produced the lowest yields for the season.

All the materials used in this study checked Alternaria and Septoria leaf spot infection.

All sprayed plots showed a gain over the unsprayed plots.

Spraying not only increased the yield above the unsprayed check plots but also increased the quality.

Bordeaux 4-6-50, 4-2-50, Bordow, and Cuprocide (7 applications), all reached their production peaks 9 days late.

With 4 applications, Basi-cop, Coposil, Oxo-Bordeaux, and Bordeaux 4-2-50 showed the greatest returns above the cost of spraying.

Among plots receiving 7 applications, Cuprocide, Bordow, Bordeaux 4-2-50, and Copper-oxychloride showed the greatest returns above the

cost of spraying. The greatest net gain above the check was given by the Cuprocide plot.

Bordeaux 4-2-50 was the most profitable to use as a late season spray. It was also one of the most profitable materials to use when spraying throughout the season.

Delayed spraying may be recommended to those who are well informed in leaf spot diseases and also to those who set disease free plants.

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