STATION TECHNICAL BULLETIN 4 JANUARY 1944

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INTRODUCTION

Leaf spot† is the most destructive disease of sour cherry in Oregon. Other states have experienced severe losses from this disease and much experimental work on its control has been done in various midwest and eastern states. As a result of this work it has become increasingly evident that this disease exhibits great variability in its epidemiology and control under different seasonal or regional conditions. It has been demonstrated that control measures that are effective in one season or region may not be effective under other circumstances and in other regions. For these reasons it has seemed desirable to evaluate for Oregon conditions the effectiveness and safety of various copper, sulphur, and other spray materials and dusts for leaf-spot control.

THE LEAF-SPOT PROBLEM IN OREGON

The problem of sour-cherry leaf-spot control in Oregon is a local one. For a number of years previous to the experimentation started in 1939 and reported in this bulletin, bordeaux mixture was suggested by the Oregon Experiment Station for the control of leaf spot because of recommendations in midwestern and eastern states. This copper-containing spray did not give complete satisfaction, however, because of inadequate control of the disease as well as occasional injury to the fruit crop. The purpose of the investigation reported here, therefore, was to compare the control efficiency of certain other spray materials with bordeaux mixture under Oregon conditions. It is unfortunate, however, since there are so many distinctly different environmental conditions in various localities in Oregon, that these experiments were limited for the most part to one locality. A great deal may depend on environmental conditions for development of a fungous disease, and a fungicide may vary in its control as well as in injuries to the trees sprayed under slightly different climatic or environmental conditions. Then, too, cumulative results from control measures may require several seasons for best expression. For these reasons results of experiments in various localities conducted over a longer period of years undoubtedly would give much more assurance for recommendations of a spray program for ideal control with a minimum of injury to the trees and crop.

It is timely, however, to present the results of these recent spray experiments, especially under the present war conditions, since we are able with considerable satisfaction to recommend substitute spray materials for the copper-containing bordeaux mixture.

* In this work on sour-cherry leaf-spot control we gratefully acknowledge the assistance and full cooperation of R. H. Robinson, agricultural chemist, and S. C. Jones, associate entomologist, Oregon Agricultural Experiment Station; Chester Chase, orchardist, Springfield, Oregon, who cooperated by allowing the use of his Montmorency cherry orchard and spraying equipment; Mr. O. S. Fletcher, county agricultural agent, Lane County; Mr. Carl Robertson and others of the staff of the Eugene Fruit Growers Association, as well as the many chemical companies and their representatives who donated much of the spray chemicals used in the experiments reported in this bulletin.

† Caused by the fungus, *Higginsia hiemalis* (Higgins) Nannfeldt.

HISTORICAL REVIEW

Brief mention should be made here of the history of spraying for the control of cherry leaf spot in the United States. This history has been reviewed adequately in the various publications by G. W. Keitt et al. at the University of Wisconsin.* The most striking and pertinent fact revealed by this history of about 35 years of spraying experiments is that opinion on the comparative merits of sulphur-containing and copper-containing sprays for the control of leaf spot is still divided. This difference of opinion probably is due mostly to the fact that neither spray is superior to the other under all conditions.

THE CAUSAL FUNGUS IN RELATION TO CONTROL

In any discussion of experimental work dealing with the control of a fungous disease, the life history of the causal fungus and its relation to environmental conditions must be considered.

LIFE HISTORY

The cherry leaf-spot fungus infects the leaves early in the spring by means of winter spores (ascospores), which are discharged into the air from old leaves of the previous season that are matted on the ground under the trees. This discharge of ascopores takes place in Oregon through March and into April, over a period of four to six weeks according to the season.† These spores, therefore, are in the air during the blossom period and while the earliest young leaves are developing. The fungus develops in these leaves until spots of less than $\frac{1}{16}$ inch up to about $\frac{1}{8}$ inch in diameter are formed. There may be enough spots more or less to cover the entire leaf. The fungus in these spots in turn produces millions of summer spores (conidiospores), which during the damp weather reinfect other leaves or leaf and fruit stems. There are two vulnerable stages of the fungous life history, therefore, that are important in control: (1) the overwintering-ascospore stage on the ground, and (2) the spread to the new leaves, first by the winter spores from the old leaves, and later by means of the summer spores to the maturing leaves.

CONTROL

There are two phases of control based on the two stages in the development of the causal fungus, one directed toward the elimination of the overwintering, ascospore stage, and the other aimed at prevention of infection of the current season's leaves by either ascospores or by conidiospores that develop soon after the first ascosporic infections have occurred. The first comes under the heading of *sanitation* and the latter of *protective spraying* to prevent leaf and fruit infection from either spore form.

Orchard sanitation

The difficulty of controlling cherry leaf spot may be materially lessened by plowing under the old leaves before blossoming time or by rendering them

* Keitt, G. W., E. C. Blodgett, E. E. Wilson, and R. O. Magie. The Epidemiology and Control of Cherry Leaf-spot. Wisconsin Agricultural Experiment Station Research Bulletin 132: 1-117. 1937.

† A detailed description of the leaf-spot fungus under Oregon conditions is contained in a thesis by A. W. Evans, "Leaf Spot of Sour Cherry in the Willamette Valley," submitted to Oregon State College in partial fulfillment of the requirements for the degree of Master of Science, June 1941.

harmless in some other way. In recent years considerable emphasis has been placed on eradicant sprays designed to burn out the fungus in the old leaves and thus prevent the production of winter spores.

Spraying

Regardless of sanitary practices or experimentation with eradicant sprays, it is still necessary to resort to protective sprays during the growing season for complete control of the leaf-spot disease.

SPRAY EXPERIMENTS

A complete experimental project for the control of cherry leaf spot should include both *eradicant* and *protective* sprays and dusts. Because of the limitations on funds and time allotted to this project, only a few exploratory experiments were included on both eradicant sprays and protective dusts. The bulk of the work was devoted to testing protective sprays, both as to the materials and combinations used, and the time of application.

PROTECTIVE SPRAYS

Experiments toward the control of cherry leaf spot by spraying, particularly in sour cherries, during the period from 1939 through 1941, not only have given satisfaction but also have proved very enlightening. Many different types of spray material were tested, including 49 combinations of copper sprays, 11 combinations of sulphur sprays, 4 miscellaneous and organic spray materials, and 3 dusts. Unfortunately, time and funds did not permit adequate nor satisfactory tests of dusting.

Each spray material was applied at the four stages of tree development known as "preblossom," "petal fall," "shuck fall," and "two-weeks later." Combinations of these applications also were applied in such a way that it could be determined which applications were the critical ones for control. (See Tables 1, 2, and 3.) In these experiments a pressure of 300 to 350 pounds was used. All of the spray tests reported here were applied to Montmorency cherry trees in the Chester Chase orchard, Springfield, Oregon.

RESULTS

Except for the season of 1939, the results of the spray experiments are included in Tables 1, 2, and 3. Because of the late date, in the spring of 1939, at which funds for the investigation of cherry leaf spot were made available, the first sprays applied on May 1 came at the "shuck fall" stage. Even so, three applications up to June 3 were given in most cases in a schedule that included 64 combinations of copper and sulphur fungicides together with a variety of spreaders, penetrators, and stickers. The general results in 1939 indicated that copper-containing sprays (including bordeaux mixture) were not satisfactory but that sulphur-containing sprays were much better. Three applications of 6 pounds of Kolofog (a bentonite-fused wettable sulphur) plus 6 pounds of hydrated lime in 100 gallons of water gave about 100 per cent control of leaf spot. The sprays in 1940 and 1941, however, indicate that as a rule and under ordinary weather conditions up to the first of June, wettable sulphurs used alone are not effective in the control of leaf spot of sour cherries.

Several spray materials, either alone or in combination, gave satisfactory control of cherry leaf spot in 1940 and 1941. (See Tables 1 and 2.)

Sulphur sprays

Outstanding among the sulphur sprays was lime-sulphur, which consistently gave excellent control every year (Figure 1). This was applied in the following strengths and combinations (see Table 3):

(1) 2 gallons (32° Baumé) per 100 gallons of spray material.

(2) 1 gallon (32° Baumé) per 100 gallons of spray material.

(3) 2 gallons (32° Baumé) plus 6 pounds micronized wettable sulphur per 100 gallons.

(4) 1 gallon (32° Baumé) plus 3 pounds of Bentonite-fused wettable sulphur to 100 gallons.

Figure 1. Montmorency cherry orchard. Row of trees at right not sprayed; notice light colored foliage, scarcity of leaves, and thin shadows cast on the ground due to leaf-spot infection. Row of trees at left sprayed with 4 applications of lime sulphur; notice the dark, heavy foliage and dense shadows on ground.

All four of these lime-sulphur sprays gave excellent commercial control of leaf spot. It is believed that, because of the "safening" influence of wettable sulphur, one of the above mentioned combinations should be used in the later application if the weather is warm.

Copper sprays

Bordeaux mixture was the one copper spray that gave better control than the other copper sprays. At no time, however, did it equal the lime-sulphur, either in consistent control of leaf spot or in freedom from injury. Where bordeaux was used, the trees showed injury both to the leaves and in reduction of the size of fruit (Figure 2). Bordeaux mixture cannot be recommended for leaf-spot control in Oregon.

Figure 2. Effect of sprays on the size of cherry fruit. At right, unsprayed branch with few leaves and large fruit with insipid or bitterish taste. Middle branch was sprayed with 3 applications of bordeaux mixture; notice the small fruit. Branch at left sprayed with 3 applications of lime sulphur; notice good sized fruit and normal leaves.

Organic sprays

One organic material known as Fermate (ferric dimethyl-dithiocarbamate) gave excellent control of leaf spot. One and one-half pounds of the organic compound plus 1.5 pounds of hydrated lime plus ½ pound of a casein spreader were used in 100 gallons of spray. The use of such an organic material may become valuable where injury from lime-sulphur is feared.

PROTECTIVE DUSTS

Some dusts were included in the first plans for this project, but lack of funds and time necessitated dropping this phase of the work, and such results as were obtained were not considered of sufficient significance to include here.

ERADICANT SPRAYS

In one plot winter strength lime-sulphur spray (10 gallons per 100) was applied to the trees as well as to the ground, and in another plot 1½ per cent Elgetol was sprayed on the ground. In both cases the ground was thoroughly soaked with the chemical solutions, but as far as could be observed these applications produced no apparent reduction in the severity of leaf-spot infection. In any event orchard sanitation practices should not take the place of the recommended spray program to prevent leaf infection, but should be considered as supplementary devices.

DISCUSSION

The results of three years' experience in experimental spraying for the control of leaf spot in sour cherries have yielded a practical solution to the problem. All of the questions may not be answered, but a considerable degree of success has been achieved. For instance, the question of injury to sour-cherry leaves or fruit by the application of lime-sulphur in strengths now recommended may take a considerable period of years to answer. Under the conditions of our experiments, however, which reached temperature of 87°, little appreciable damage was done by lime-sulphur (32° Baumé) 2 gallons per 100 gallons of spray. What might happen another year is somewhat problematical.

Some other pertinent facts brought out by the experiments may be enumerated:

1. The critical period for control of cherry leaf-spot depends on the weather and not on the stage of development of cherry blossoms and leaves. For instance, control was obtained as follows: in 1939 by the "shuck fall" or later applications; in 1940 by the "petal fall" application; and in 1941 by a late "shuck fall," or even the "two-weeks later" application. Since this critical period for control cannot be predicted, therefore, recommendations to insure control should call for the 3 sprays: "petal fall," "shuck fall," and "two-weeks later."

2. Thorough coverage should be emphasized. Wherever the spray does not hit and spread, leaf spot will develop.

3. One of the outstanding facts previously known but emphasized by our results is that fungicidal sprays must be tested under local climatic conditions. Copper sprays for leaf-spot control are not satisfactory under western Oregon conditions, whereas lime-sulphur gave consistently better control. Just the opposite usually is considered true in many middle western and eastern states.

4. Fermate is very promising as a spray for leaf-spot control. The one-year trial gave as good control as lime-sulphur without any leaf injury.

RECOMMENDATIONS FOR SOUR-CHERRY LEAF-SPOT CONTROL IN WESTERN OREGON

The following recommendations are based on the results of three years' spraying experiments for leaf-spot control:

Lime-sulphur has consistently given excellent control. Lime-sulphur, therefore, is recommended with the caution that there is a remote possibility of lime-sulphur burn if certain warm and humid weather conditions should prevail. Such conditions might arise at the time of the third spray application. Our experiments indicate that wettable sulphur will control leaf spot in *warm* weather. To avoid the possibility of lime-sulphur burn, therefore, wettable sulphur (6 pounds to 100 gallons of spray) may be substituted for, or mixed with, lime-sulphur in the third spray. If the mixture is to be used, add 1 gallon of lime-sulphur and 3 pounds of a micronized wettable sulphur to 100 gallons of water.

If Fermate becomes commercially available, it may be substituted for lime-sulphur. It is used as follows: 1½ pounds Fermate plus 1½ pounds hydrated lime plus ⅓ pound casein spreader in 100 gallons of water.

SPRAY SCHEDULE

(1) *Petal Fall Spray.* Lime-sulphur 2-100. Apply as soon as most of the flower petals have fallen.

(2) *Shuck Fall Spray.* Lime-sulphur 2-100. Apply when most of the "shucks" have fallen from the young green fruit.

(3) *Two-Weeks-Later Spray.* Lime-sulphur 2-100. Apply 2 weeks after shuck fall spray.

(4) *After-Harvest Spray.* If the disease has not been well controlled up to harvest time, it may be desirable to make an additional application when the fruit is off, in order to prevent too much defoliation before the summer growth of the trees and fruit-bud formation is completed. Use lime-sulphur or one of the following substitutes.

HOT WEATHER SUBSTITUTES

If, at the time of the third or fourth applications, hot, humid weather should cause fear of lime-sulphur burn, any one of the listed substitutes may be used:

(1) Wettable sulphur 6 pounds, water 100 gallons.

(2) Lime-sulphur 1 gallon, bentonite-fused sulphur 3 pounds, water 100 gallons.

(3) Fermate 1½ pounds, hydrated lime 1½ pounds, casein spreader ⅓ pound, water 100 gallons.

For the preparation of sprays see Oregon Agricultural Experiment Station Bulletin 393.

Table 1. Results of Control of Leaf Spot and Defoliation by Various Spray Combinations in 1940

Infection of leaf spot on unsprayed trees averaged 70-80 per cent

	Spray materials used: dosages per 100 gallons*	Percentage control of leaf spot and defoliation		
		Petal fall application only	Petal fall, and shuck fall applications	Petal fall, shuck fall, and two-weeks-later applications
		Per cent	*Per cent*	*Per cent*
1)	2 lbs. Cupro-K + ½ pound bentonite	71–80	81–90	86–90
2)	2 pounds Cupro-K + 2 pounds hydrated lime	86–95	86–95	76–85
3)	2 pounds Cupro-K + ½ pound zinc sulphate + ⅛ pound sodium carbonate	56–65	66–75	66–75
4)	2 pounds Cupro-K + ½ pound calcium sulphate	81–90	76–85	71–80
5)	2 pounds Cupro-K + ½ pound zinc sulphate	71–80	76–85	71–80
6)	2 pounds Cupro-K + 1 pint petroleum oil (viscosity 55)	71–80	71–80	71–80
7)	2½ pounds Apple Coposil + Fluxit	66–75	51–60	56–65
8)	2½ pounds Apple Coposil + ½ pound bentonite	76–85	71–80	61–70
9)	2½ pounds Apple Coposil + 2½ pounds hydrated lime	71–80	76–85	76–85
10)	2½ pounds Apple Coposil + ½ pound zinc sulphate + ⅛ pound sodium carbonate	76–85	76–85	81–90
11)	2½ pounds Apple Coposil + ½ pound calcium sulphate	66–75	71–80	76–85
12)	2½ pounds Apple Coposil + ½ pound zinc sulphate	81–90	81–90	81–90
13)	2½ pounds Apple Coposil + 1 pint Orthex + 2½ pounds hydrated lime	76–85	86–95	76–85
14)	1½ pounds Spraycop + ⅛ pound bentonite	86–95	81–90	86–95
15)	1½ pounds Spraycop + 1½ pounds hydrated lime	81–90	76–85	81–90
16)	1½ pounds Spraycop + ½ pound zinc sulphate + ⅛ pound sodium carbonate	81–90	76–85	76–85
17)	1½ pounds Spraycop + ½ pound calcium sulphate	81–90	81–90	81–90
18)	1½ pounds Spraycop + ½ pound zinc sulphate	71–80	71–80	76–85
19)	1½ pounds Spraycop + 1 pint petroleum oil (viscosity 55)	71–80	81–90	81–90
20)	1½ pounds copper arsenate	61–70	71–80	71–80
21)	1 pound Cuprocide 54Y + 2 pounds hydrated lime	86–95	86–95	86–95
22)	1 pound colloidal copper oxide + ⅛ pound zinc sulphate	76–85	76–85	76–85
23)	1 pound colloidal copper oxide + 1 pint penetrol	76–85	76–85	71–80
24)	1 pound colloidal sulphur	41–50	41–50	41–50
25)	2-2-100 bordeaux	91–100	86–95	91–100
26)	5 pounds dry lime sulphur	81–90	86–95	86–95
27)	6 pounds Mike sulphur	66–75	56–65	81–90
28)	6 pounds Kolofog	66–75	51–60	56–65
29)	2 pounds Z-O + 2 pounds hydrated lime	71–80	81–90	66–75
30)	1 pound organic copper	71–80	36–45	66–75

* One-third pound Fluxit spreader was added to all combinations except Nos. 13, 23, 26, and 30.

Table 2. Results of Control of Leaf Spot and Defoliation by Various Spray Combinations in 1941

Infection of leaf spot on unsprayed trees averaged 60-80 per cent

Spray materials used; dosages per 100 gallons	Percentage control of leaf spot and defoliation					
	Preblossom application	Preblossom, petal fall, and shuck fall applications	Petal fall application	Petal fall and shuck fall applications	Shuck fall application	Shuck fall and 2 weeks later applications
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
6 pounds Sulfuron	61–70	71–80	61–70	71–80	61–70	61–70
6 pounds Mike sulphur	41–50	85–95	65–75	75–85	55–65	81–90
6 pounds Kolofog	31–40	51–60	51–60	51–60	51–60	51–60
6 pounds Kolofog + 6 pounds hydrated lime	45–55	85–95	41–50	81–90	55–65	85–95
6 pounds homemade wettable sulphur + 3 oz. Vatsol	51–60	61–70	41–50	31–40	25–35	45–55
1½ pounds Fermate + 1½ lbs. hydrated lime + ¼ pound Fluxit	41–50	75–85	95–100	85–95	65–75	95–100
½ pound yellow Cuprocide + ½ per cent summer oil	51–60	51–60	45–55	55–65	51–60	55–65
½ pound yellow Cuprocide + ½ per cent S.E.C. oil	21–30	41–50	41–50	51–55	51–60	71–75
½ pound yellow Cuprocide + B-1956 Spreader (1-3200)	51–60	51–60	51–60	61–70	51–60	61–70
1 pound Copper A compound + ¼ pound Fluxit	41–50	51–60	51–60	61–70	41–50	51–60
1 pound Copper A compound + ½ pound bentonite + ¼ pound Fluxit	41–50	51–60	51–60	61–65	41–50	61–65
1½ pounds Spraycop + ½ pound Bentonite + ¼ pound Fluxit	41–60	51–60	51–60	61–65	51–60	61–65
1½ pounds Spraycop + 1 pound Filmfast	31–40	41–50	41–50	51–60	31–40	51–60
4 pounds Tribasic copper sulphate + ¼ pounds Fluxit	51–60	51–60	61–65	61–65	61–65	65–70
2 pounds U.S.R.C. Fungicide No. 375 + 4 pounds hydrated lime	31–40	85–90	51–60	81–90	71–80	81–90
2 pounds U.S.R.C. organic fungicide No. 336	31–40	41–50	41–50	51–60	41–50	41–50
2-2-100 bordeaux + 2 ounces Vatsol	41–50	51–60	51–60	61–70	51–60	81–90
2-1-100 bordeaux + 2 ounces Vatsol	25–35	35–45	35–45	45–55	45–55	61–70
2-1-100 bordeaux + 1 quart summer oil	31–40	55–65	35–45	51–60	51–60	45–55
1-1-100 bordeaux + 2 ounces Vatsol	41–50	51–60	51–60	51–60	41–50	81–90
2-3-100 burgundy mixture + 2 ounces Vatsol	35–45	35–45	35–45	41–50	35–45	25–35
2-1½-100 burgundy mixture + 2 ounces Vatsol	25–35	25–35	15–25	25–35	25–35	31–40

Table 3. Results of Control of Sour-Cherry Leaf Spot and Defoliation by the Use of Lime Sulphur (32° Baumé)

Years 1940 and 1941

Percentage of control by applications of spray at stage of tree development indicated

Spray material	Pre-blossom only	Pre-blossom and petal fall	Pre-blossom; petal fall; and shuck fall	Pre-blossom; petal fall; shuck fall; and 2 weeks later	Pre-blossom; petal fall; and 2 weeks later	Pre-blossom; and shuck fall	Pre-blossom; shuck fall; and 2 weeks later	Pre-blossom; and 2 weeks later	Petal fall only	Petal fall; and shuck fall	Petal fall; shuck fall; and 2 weeks later	Petal fall; and 2 weeks later	Shuck fall only	Shuck fall; and 2 weeks later
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
2 gallons per 100 gallons of spray (1940)	.....	.....	.....	95–100	.....	.....	.....	.....	81–90	81–90	91–100	81–90	1–10	21–30
2 gallons per 100 gallons of spray (1941)	25–35	25–35	81–90	91–100	91–100	85–95	91–100	91–100	61–70	85–95	95–100	85–95	71–80	95–100
1 gallons per 100 gallons of spray (1941)	25–35	41–50	75–85	95–100	85–95	81–90	95–100	85–95	25–35	71–80	95–100	81–90	51–60	85–95
2 gallons + 6 pounds Mike-sulphur per 100 gallons of spray (1941)	45–55	55–65	81–90	95–100	91–95	81–90	91–100	81–90	41–50	85–95	85–95	85–95	81–90	95–100
1 gallon + 3 pounds Kolofog per 100 gallons of spray (1941)	45–55	55–65	85–95	95–100	91–100	75–85	91–100	85–95	61–70	85–95	95–100	91–100	85–95	91–100