STUDIES ON THE CONTROL OF CHERRY LEAF SPOT, COCCOMYCES HIEMALIS HIGGINS

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STUDIES ON THE CONTROL OF CHERRY LEAF SPOT,

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TABLE OF CONTENTS

INTRODUCTION*

Cherry leaf spot caused by the fungus *Coccomyces hiemalis* Higgins is the most serious and destructive disease of cherries in Michigan. The effects of this disease are the main limiting factors in cherry production. Epiphytotics of this disease in the last eleven years have occurred in Michigan in 1928 (23), 1929 (14), 1935 (20), 1937 (22, 80) and 1938 (81).

The most striking and apparent effect of the disease is premature defoliation of the trees. Loss of leaves, occurring before harvest, may cause an uneven and delayed ripening of the fruit. Repeated attacks of leaf spot may seriously lower the quality and production of the crop for several years. Trees that have prematurely lost their foliage during a single season may be winter killed during the following dormant period. Trees that have been defoliated several years in succession seldom survive a severe winter.

After effects of leaf spot infection may become evident in years following defoliation. Delayed blossoming periods with fewer and

*Contrary to the usual practice it became desirable to have certain portions of the information obtained in the course of the research published in short papers prior to the completion of the thesis as follows:

Cation, D. and C. W. Robertson. Basicop as a cherry spray. Michigan Agricultural Experiment Station Quarterly Bulletin 20: 199-210. 1938.

Robertson, C. W. and D. Cation. Basicop as a cherry spray in 1938. Michigan Agricultural Experiment Station Quarterly Bulletin 21: 291-295. 1939.

smaller blossoms have been noted. Reductions in fruit size and number of cherries may occur as well as delayed and uneven ripening of the fruit.

Growth of old and new wood may be reduced. Fewer fruit spurs may be formed. Hardening of the wood is also a resultant of leaf spot infection following severe defoliations of the previous year. Galloway (45) states that the active wood of defoliated nursery stock hardens in such a manner that the buds can not be inserted or that imperfect unions with the stock result causing the buds to die. Buds or grafts that grow are checked by premature defoliation to such an extent that it is questionable whether the trees ever fully recover.

The frequency with which this disease occurs and the seriousness of the residual effects makes it apparent that satisfactory control methods for the leaf spot disease are necessary for the successful culture of cherries in Michigan.

Satisfactory control of cherry leaf spot may be gained by eradication of over-wintered leaves and the proper use of protectant fungicides. Investigators have recognized that the amount of primary infection is limited by early spring destruction of the old leaves since Higgins (54) proved the means by which the fungus over-winters. Arthur (5) described an ascogenous form on plum leaves similar to Coccomyces hiemalis Higgins and apparently realized the significance of the old leaves in the life history when he advised their destruction. Pammel (70) in 1891 described a similar perfect stage but, as with Arthur, the genetical connection with the imperfect stage was not proved. Keitt (58) found that early clean cultivation in the spring greatly reinforced the spray schedule in Wisconsin. He also found (62) that eradicative sprays applied to the leaves in the fall prevented or materially reduced the amount of primary infection in experimental plats.

Main reliance for control of the disease in commercial cherry production is placed upon the use of protectant fungicides supplemented by destruction of the old leaves by early spring cultivation when the latter does not interfere with recommended horticultural practices. Thus, investigations conducted to devise measures of control for this disease have dealt largely with sprays. Since the production of the fruit on a large scale began, much experimental work had been conducted on the types of spray materials, the methods and timeliness of application.

HISTORICAL REVIEW

As a result of observations made in 1886, Arthur (5) suggested the use of sodium hyposulphite or potassium sulphide as spray materials for the control of plum leaf spot.* The following year Arthur (6) conducted experiments using six applications of potassium sulphide solution. The foliage of the treated trees was retained longer and appeared more vigorous than that of the untreated trees.

The first attempt to control leaf spot of cherries, according to Fairchild (40), was inaugurated by Galloway in 1889. In 1890 he (42) made trials of ammoniacal copper carbonate and bordeaux mixture using six applications at 12 day intervals beginning about May 1. Observations indicated that the two materials were equally efficient and that each treated plat was superior to the unsprayed control. Experiments (45) conducted in 1891, 1892 and 1893 on Black Tartarian, Governor Wood and Early Purple varieties demonstrated that trees sprayed with bordeaux mixture 6-4-22 made an increased growth over untreated trees, a fact he could not explain as entirely due to the efficiency of the spray as a fungicide and insecticide. No difference was noted between early or late sprayed stock nor was there any perceptible difference between plats receiving 7 and 5 sprays.

Thaxter (99) in 1889 reports the application of bordeaux mixture 6-6-22 on two Lombard plum trees leaving a third as a control tree.

*Coccomyces prunophorae Higgins (55), since shown to be a distant fungus from the causal organism of cherry leaf spot Coccomyces hiemalis Higgins. (54).

Three sprays were applied and the treated trees held their foliage until October while the control tree was defoliated in August. Observations (100) on a cherry and plum orchard to which an application of bordeaux mixture had been made, showed that the treated trees held their foliage free from leaf spot while the untreated trees were defoliated early in the season. An instance is also cited in which several plum trees received the same treatment and retained their foliage.

Fairchild (37, 38, 43, 44) in 1891 used an ammoniacal solution of copper carbonate in comparison with bordeaux mixture 6-4-22 as spray materials for cherry leaf spot control. Mazzard and Mahaleb nursery stock was used, one half of each receiving 6 sprays while the other half received only 3 sprays. Infections were too slight and appeared too late in the season to indicate the comparative efficiencies of the two fungicides, although the treated trees had fewer infections than the untreated. In 1892 (39) he again tested the same materials on Mazzard stock and on Windsor and Yellow Spanish nursery varieties budded on Mahaleb stock. Trees receiving 6 applications had superior foliage to the untreated trees and bordeaux mixture 2-2-15 was slightly superior to the ammoniacal solution. Treatments with the latter produced foliage injury. Similar results were obtained on all varieties.

Due to the injury caused by the ammoniacal solution of copper carbonate, Fairchild (39) tested only bordeaux mixture the following year, and, since little evidence of the disease was noted, there were no indications as to the fungicidal effectiveness of the spray material. In 1894 he (40) reported that bordeaux mixture might be considered a specific for the control of cherry leaf spot of nursery stock. Tests indicated that the best results were obtained when the first spray was applied directly after the foliage was fully formed and repeated at two week intervals until six applications were made.

Green (49) stated in 1891 that trees sprayed with bordeaux mixture 4-4-50 held their foliage until late in the season while unsprayed trees were defoliated early in August. Although the number of applications necessary was not determined, it was pointed out that one helped "a great deal" and that probably 2 or 3 would be sufficient.

Pammel (70) in 1891 conducted a one-spray and three-spray program with an ammoniacal copper carbonate solution on nursery stock of the Griotte Du Nord variety. Distinct differences were noted, there being many more leaves on the three-spray plat than on the trees receiving one spray and the control trees lost much more foliage than either treated plat. Bearing Gros Gobet trees were given three applications of bordeaux mixture 6-4-22 and two sprays of ammoniacal solution of copper carbonate. Excellent control was obtained on the treated trees while the controls had considerable defoliation during the latter part of August. Similar results were noted on trees of the Galatin variety. No infected leaves were found on Duchesse D'Angouleme trees that received two sprays of bordeaux mixture 6-4-22. The control tree was partially defoliated early in the season. Additional treatments were made with ammoniacal copper carbonate solution but the disease was so slight that even the untreated controls were uninfected.

In 1892 Pammel (71) applied 10 sprays of ammoniacal copper carbonate solution to a Russian variety budded on Mahaleb seedlings and obtained fully 50 percent more leaves and better growth on the treated than on the untreated stock. Seven applications of bordeaux mixture 12-8-50 were applied to seedling Russian cherries and on Russian varieties budded on Mahaleb stock. The treated trees had fewer infested leaves and superior growth to the control trees in each case. King's Morelle, Griotte du Nord and Sklanka varieties of budded cherries received 5 applications of bordeaux mixture 12-8-50, and midseason observations showed almost 50 percent more leaves per treated tree than on the untreated trees.

Pammel (72) estimated in 1893 that three-fourths of the leaves remained on four cherry trees of the Gros Gobet variety given four sprays of bordeaux mixture 6-4-45 as compared with the unsprayed control which was almost completely defoliated.

Pammel and Carver (73) tested five-spray programs of bordeaux mixture 6-4-22 and ammoniacal solution of copper carbonate in 1894. Superior growth and approximately 80 percent more leaves resulted on the bordeaux mixture treated trees as compared with the untreated. Results were similar but less pronounced with ammoniacal copper carbonate solution and, in addition, there was a slight amount of foliage injury and infections per leaf were more numerous.

Beach (10) conducted experiments in 1895 on Montmorency, Reine Hortense and Early Richmond varieties using a three-spray program of eau celeste soap mixture and of bordeaux mixture. Although it was noted that the eau celeste soap mixture produced serious injury to the foliage, little information was gained in regard to leaf spot control because even the untreated control trees had excellent foliage at the end of the season. Continuation of these experiments was made in 1896 (11) in an effort to determine the timeliness and the number of applications of bordeaux mixture necessary to control the disease. Disease incidence was slight even on the control trees, and results of the tests were of little value although no spray injury to the foliage was found.

Beach, Lowe, and Stewart (12) stated in 1899 that the disease could be controlled satisfactorily by the proper applications of bordeaux mixture but that these treatments could not be applied at the opportune times because the spray residue seriously interfered with the market value of the fruit. Consequently no positive recommendation was given but a pre-bloom and petal-fall application of bordeaux mixture was suggested with the possible addition of a third spray.

Taft (95) in 1894 recommended bordeaux mixture 4-3-32 for a pre-bloom and petal-fall application and a summer spray 10-14 days later. As a supplementary spray the latter was to be repeated if signs of brown rot appeared. To eliminate spray residue, ammoniacal copper carbonate solution was advised for the fourth regular spray. The following year he (96) advised a pre-bloom spray of copper sulphate solution 1-25, a petal-fall and a summer spray 10-14 days later of bordeaux mixture 4-3-40. The latter was to be repeated if symptoms of brown rot appeared. The fourth regular summer spray, 10-14 days later, consisted of an application of weak copper sulphate solution 1-250 or 1-500. If leaf spot infections continued to occur, the fourth spray was to be repeated at suitable intervals. The 1898 spraying calendar for Michigan (97) recommended a dormant spray of copper sulphate solution 1-15 or 1-25 or bordeaux mixture 4-4-40, and the same spray 2 to 3 weeks later and repeated as often as the occasion demanded.

Stewart, Rolfs, and Hall (89) in 1900 reported the disease to be of little concern to bearing trees or nursery stock, although Mazzard cherry seedlings were frequently attacked.

Rolf (82) in 1907 advised sprays of bordeaux mixture 5-5-50 as soon as the leaves came out, followed by a second spray two weeks later. Under conditions of severe leaf spot it was thought a third and fourth application might be necessary although they should be applied only in extreme cases because the residue might seriously injure the market value of the fruit.

Hein (53), experimenting with bordeaux mixture in 1908, found that little benefit was derived from a pre-blossom spray although leaf spot became severe when the last application, equivalent to the four-weeks spray, was omitted. Trees sprayed with bordeaux mixture after the leaves were almost fully developed showed very few yellow leaves the latter part of the season while the unsprayed control trees were one-half defoliated in mid-season. The recommendation as a result of these experiments was a three-spray program, a petal-fall and two additional sprays applied at 14 to 18 day intervals.

Due to the encouraging results obtained with self-boiled lime-sulphur on peach and apple foliage in 1908 (85), Scott tested self-boiled lime-sulphur 10-10-50 and 6-6-50 and lime sulphur 1-40 in comparison with bordeaux mixture 2-4-50 on cherries the following year (86). Varieties Montmorency, Dyehouse, Early Richmond, Wragg, and Ostheimer received three sprays, the first beginning one month after bloom. The self-boiled lime-sulphur 10-10-20 and lime sulphur 1-40 sprayed trees were almost equally perfect in foliage. The self-boiled lime-sulphur 6-6-50 was nearly as efficient as the 10-10-50 concentration but was considered slightly too weak for the best results. The plat treated with bordeaux mixture exhibited no injury and the disease was almost entirely prevented while the controls were completely defoliated.

Wilcox and Stone (103) in 1909 recommended applications of bordeaux mixture 3-3-50 at pre-bloom, at shuck-fall, a third spray two weeks after shuck-fall, and a fourth spray two weeks later.

In 1910 Norton and Norman (69) advised applications of bordeaux mixture 3-6-50 as soon as the leaves were out and a second spray two weeks later.

Rumsey, Giddings, and Dacy (83) recommended in 1911 the use of self-boiled lime-sulphur or bordeaux mixture 3-3-50 or 3-5-50 when the leaves are expanding and a second spray 3 or 4 weeks later.

Clinton and Britton (24) used a three-spray program of home-made lime sulphur 1-60 in 1912 and obtained no evidence of injury to the foliage but obtained no information in regard to the fungicidal value of the mixture since there was very little leaf spot infection.

The use of bordeaux mixture 5-5-50 or liquid lime sulphur 1-50 was advised in 1914 by V. B. Stewart (91) for nursery stock when the first year buds were 8 to 10 inches in height and repeated at two week intervals throughout the summer until 5 to 7 applications had been made. Superior sticking qualities and less burning of the foliage was obtained by the addition of 1½ pounds of iron sulphate to each 50 gallons of the lime sulphur solution.

Cook (25) stated in 1915 that cherry leaf spot can be controlled by after-harvest applications of self-boiled lime sulphur. In the same circular Headlee, Blake, and Cook recommended the application of self-boiled lime sulphur with 3 pounds of lead arsenate at petal-fall and when the fruit is the size of a small pea. An after-harvest application of self-boiled lime-sulphur was also advised.

V. B. Stewart (92) made a comparative trial of liquid lime sulphur 2-100 and commercial bordeaux mixture 10-10-100 on Tartarian nursery stock. The sprayed stock was far superior to the unsprayed control trees and slightly superior growth was obtained on trees treated with lime sulphur as compared with those sprayed with bordeaux mixture. The following year, first year Tartarian stock treated with a six-spray program of lime sulphur 2-100 showed a marked increase in diameter in addition to a slight increase in height over the unsprayed control trees.

Brooks and Fisher (15), in an attempt to control brown rot Sclerotinia cinerea (Bon.) Wor. in 1916, obtained no foliage injury on Royal Ann or Black Republican varieties of sweet cherries with either bordeaux mixture 2-4-50 with 2 pounds of resin-fishoil soap, liquid lime sulphur 1-50 or self-boiled lime-sulphur 8-8-50 with 2 pounds of resin-fishoil soap.

In 1914 Cooper (27) recommended bordeaux mixture 2-3-50 or self-boiled lime-sulphur 8-8-50 for a pre-bloom, a shuck-fall and a third spray two weeks after shuck-fall.

Fisher (41) noted, as a result of the application of fungicides in 1915, 1916, and 1917, that sweet cherries were considerably reduced in size. Bordeaux mixture 2-4-50 and self-boiled lime-sulphur 8-8-50 caused production of valueless fruit due to shrivelling. This condition was not as pronounced with liquid lime sulphur 2-100. Portions of certain trees received two applications of bordeaux mixture, the first as soon as the cherries began to color which was followed by the second spray two weeks later. It was found that the reduction of size of ripe sweet cherries was proportional to the amount of alkaline material in the spray. This condition was thought to be caused by excessive transpiration due to the destruction of the waxy bloom of the fruit.

V. B. Stewart (93) in 1916 compared sulphur-arsenate of lead dust 90-10 with liquid lime sulphur 1-50 on Tartarian nursery stock using a seven-spray program. Due to heavy seasonal rainfall, it was difficult to protect the new growth thoroughly. The latter part of August the average loss of leaves in the unsprayed plat was 37 pe rcent, the dusted plat 8 percent and in the sprayed plat 15 percent. The location of the sprayed plat partially accounted for the relative increased efficiency of the dust over the spray. V. B. Stewart (94) reported the same experiments again in 1917 with slightly different percentages in the amount of defoliation. Approximately 68 percent of the leaves were lost from the untreated controls in 1916 while sulphur-arsenate of lead 90-10 dusted trees lost only 16 percent.

Roberts and Pierce (79) in 1919 tested the value of numerous commercial and home-made copper and sulphur materials in Michigan. Three applications were made, the petal-fall, the three-weeks, and the after-harvest spray. Trees treated with self-boiled lime-sulphur showed almost no leaf spot control while bordeaux mixture 3-4-50 and liquid lime sulphur 2½-100 gave excellent control. Three applications of liquid lime sulphur were not sufficient to control severe attacks of leaf spot but a program of petal-fall, two-week, four-week, and after-harvest sprays gave excellent control of the disease. Leaf spot was not satisfactorily controlled with applications of dust although there was less defoliation on the dusted plats than on the control trees. Bordeaux mixture produced severe injury on sweet cherries and the English Morello and Wragg varieties of sour cherry and it was also found necessary to reduce the concentration of liquid lime sulphur to 1-50.

Barss (8) tested bordeaux mixture 4-4-50 with soap spreader, liquid lime sulphur 1-45, and Atomic Sulphur 6-50. Six sprays were applied in such a manner as to give an indication of the separate value of each spray. Results indicated that the first and last two applications were of no value for the control of leaf spot. Trees receiving the three intervening sprays of bordeaux mixture had excellent control. Atomic Sulphur controlled the disease comparatively well. Plats sprayed with liquid lime sulphur had such severe burning of the foliage and defoliation that no data could be taken upon the fungicidal efficiency of the material. Foliage sprayed with bordeaux mixture was the best appearing and was retained the longest in the experimental plats. Unsprayed controls were severely defoliated. Tests were conducted in 1917 but no information was obtained since there was a complete absence of infection. Barss recommends, from data collected in these experiments, applications of bordeaux mixture 4-4-50 with spreader beginning about May 1 and repeated at 3 to 4 week intervals until dry summer weather is permanently established. He considers that later applications might be necessary if rainy periods developed throughout the summer.

Keitt (58) tested self-boiled lime-sulphur 8-8-50, Atomic Sulphur 5-50, Barium Sulphur 3-50 and various concentrations of bordeaux mixture and lime sulphur. Four sprays were applied, a late pre-bloom, petal-fall, two weeks, and an after-harvest application. Results of two years' experiments (1917-1918) indicated that bordeaux mixture and lime-sulphur gave satisfactory control while the other spray materials failed to control the disease adequately. Comparative results obtained with bordeaux mixtures 4-4-50, 3-3-50, and 2-2-50 were almost equal. Comparatively good commercial control was obtained with the formula 1-1-50 one year but it is considered took weak for general recommendations. Lime sulphur 1-30, 1-40, and 1-50 satisfactorily controlled the disease and produced no injury to the foliage. Arsenate of lead 3/4-50 or 1-50 was used in all sprays and it was found that where lime sulphur was used without the insecticide the spray was less effective in the control of leaf spot. When the pre-bloom spray was omitted, the control was as good as the four-spray program. Omission of the after-harvest spray gave results almost as satisfactory as where it was applied. Resultant recommendations advised applications of bordeaux mixture 3-3-50 or lime sulphur 1-40 or 1-30 at petal-fall, two weeks later and also an after-harvest spray if considered necessary.

F. C. Stewart (90) based New York recommendations for cherry sprays in 1919 on Keitt's work (58) in Wisconsin, advising two or three sprays of bordeaux mixture 3-3-50 or lime sulphur 1-40 applied as petal-fall, two-weeks, and after-harvest applications.

In 1920 Coons (26), basing recommendations upon the work of Roberts and Pierce (79), advised applications of bordeaux mixture 4-4-50 or liquid lime sulphur 1½-50 at petal-fall, about three weeks later, and directly after the fruit was harvested.

Dutton (30) in 1918 and 1920 tested comparatively dilute lime sulphur and dusting sulphur on Montmorency and English Morello cherries. The dust did not control the disease. Dilute lime sulphur adequately controlled leaf spot on English Morellos until late in September. Infections were so slight on the Montmorency control trees that no information was obtained in regard to disease control on this variety.

Anderson (1) found in 1920 that either liquid lime sulphur 1-40 or bordeaux mixture applied at petal-fall and two weeks later would adequately control the disease. Addition of lead arsenate seemed to increase the fungicidal value of the spray, and iron sulphate 1½-50 decreased the amount of injury to the foliage.

In 1920 Sanders and DeLong (84) applied petal-fall, two-weeks, and after-harvest sprays of bordeaux mixture 3-3-50 with 1 pound of lead arsenate, hydrated lime-sulphur-arsenate of lead dust 50-45-5, lime sulphur 1-40, and sulphur-arsenate of lead dust 90-10. The trees treated with bordeaux mixture showed between 30 and 40 percent defoliation on September 19, the hydrated lime-sulphur-arsenate of lead dusted plat 35-45 percent defoliation, the lime sulphur sprayed plat 25 percent of the leaves infected and a slight defoliation. The sulphur-arsenate of lead dusted trees showed 25 percent of the leaves infected and no defoliation. The results indicated that the sulphur-arsenate of lead dust was superior to the other treatments due to the relatively high efficiency in control of leaf spot, curculio and slug.

Barre (7) found in 1922 that leaf spot was controlled very well by bordeaux mixture 2½-6-50 applied as petal-fall, three-weeks, and after-harvest applications on all varieties of sour cherries included in the tests except the Wragg and English Morello cherry.

Dutton and Johnston (31) in 1920 tested comparatively liquid lime sulphur 2½-100, bordeaux mixture 4-6-50, sulphur dust, and dehydrated copper sulphate (15 percent dehydrated). Tests in 1921 included liquid lime sulphur 3-100, bordeaux mixture 4-7-50, sulphur-lime-arsenate of lead dust 80-10-10 and dehydrated copper sulphate (20 percent dehydrated) with 10 percent talc. Petal-fall, two-weeks, four-weeks, and after-harvest sprays were applied on the Montmorencys and, in addition, a pre-harvest spray was applied on the English Morellos both years. Four-weeks and after-harvest sprays were omitted on the Montmorencys both years since there was little leaf spot. Leaf spot was not severe on the unsprayed control trees in 1920. The disease was never serious on the Montmorencys and even the dusted plats showed no defoliation at the end of the season, although the sulphur dusted plats had less infection than the copper dusted plats. Slight infection was found early in the season in the liquid lime sulphur sprayed plat. Bordeaux mixture caused severe foliage injury on the English Morellos and slight injury on the Montmorencys. Bordeaux mixture, on the English Morellos ranked highest in fungicidal efficiency, liquid lime sulphur second, and the two dusts slightly lower than lime sulphur. Results in 1921 were less conclusive, leaf spot control being almost perfect with every material. No spray injury to the foliage was noted in 1921 although dwarfing of the English Morello cherries was noted in plats sprayed with bordeaux mixture.

In experiments designed to determine the number of applications necessary after the harvest of the fruit, Moore (68) concluded in 1923 that three sprays of liquid lime sulphur 2½-100, beginning directly after harvest in addition to the regular petal-fall and second spray at the time the fruit is well formed, would give good commercial control.

Dutton and Wells (33) found that bordeaux mixture 8-14-100, 6-14-100, and 6-10-100 (lump lime) produced satisfactory control in experiments conducted in 1922, 1923, and 1924, respectively. It was found, however, in certain instances that severe foliage injury and considerable dwarfing of the fruit occurred. Liquid lime sulphur 2½-100 or 3-100 gave as satisfactory control as bordeaux mixture although, generally, the control was not as complete on English Morellos. Lime sulphur caused a small amount of foliage injury and only a slight reduction in fruit size. Pyrox 18-100 caused severe foliage injury and defoliation but the fungicidal effectiveness of the material was not tested adequately. Colloidal sulphur 10-100 and copper or sulphur dusts caused no apparent foliage injury and very slight dwarfing of the fruit but did not control the disease satisfactorily.

Keitt and Jones (60) found in 1923 that the pre-blossom spray might be omitted from the schedule since cherry leaf spot makes little progress during the cool period of early spring and develops rapidly in the early part of the summer, reaching maximal development during warmer temperatures.

Keitt (59), speaking before the Ohio State Horticultural Society in 1923, stated that various concentrations of liquid lime sulphur, self-boiled lime-sulphur, dry lime sulphur, wettable sulphur, and barium tetrasulphide were tested over a period of years for the control of cherry leaf spot. Results indicated that bordeaux mixture 3-3-50 gave the most satisfactory control although it occasionally caused injury. Liquid lime sulphur applied as a three-spray program adequately controlled the disease although it was not sufficient in abnormally wet seasons. Pre-blossom sprays were found to be of value in certain years. The after-harvest application, although generally recommended, was of no value under certain seasonal conditions.

Brooks and Fisher (16) conducted experiments for the control of brown rot on Napoleon, Black Republican, and Lambert varieties of sweet cherries. Bordeaux mixture 2-4-50 with 2 pounds of rosin-fishoil soap, 8-8-50 self-boiled lime-sulphur with 2 pounds of rosin-fishoil soap and liquid lime sulphur 1-50 were tested. A three-spray program of these materials produced no spray injury in 1915. Similar results were obtained the following year with a four-spray program but the cherries from the self-boiled lime-sulphur sprayed plat were smaller than average. Lime sulphur caused foliage injury in 1917 and cherries from the bordeaux and self-boiled lime-sulphur sprayed plats were smaller than cherries from the untreated controls. The following year similar treatments produced foliage injury on the plat treated with lime sulphur, and the cherries from the plat sprayed with bordeaux mixture were somewhat smaller than those from the unsprayed trees. In 1919 liquid lime sulphur 1-50 with casein spreader, neutral bordeaux mixture 4-50 with rosin-fishoil soap, and sulphur arsenate of lead dust 85-15 were applied twice on Napoleons. The control trees and the dusted plats produced better appearing cherries although the dust was not as effective in the control of the disease as the sprays. Severe defoliation and yellowing was noted on bordeaux mixture sprayed plats three months after the final applications.

Toothaker (101) states in 1921 that a petal-fall application of bordeaux mixture followed by liquid lime sulphur and lead arsenate after harvest failed to control the disease.

As a result of field observations in 1921, 1922, and 1923 on the effects of various spray materials on the size of fruit, Dutton and Wells (37) conducted transpiration studies on the English Morello cherry. The water loss per unit area of leaf surface was found to be the least with unsprayed shoots, slightly more with shoots sprayed with liquid lime sulphur and significantly more with shoots sprayed with bordeaux mixture. The rate of water loss per unit area of leaf surface during a 24 hour wilting period maintained the same relationship in regard to the effects of the two spray materials. Observations and experimental evidence indicated that leaves sprayed with bordeaux mixture had a greater power to withdraw water from the green cherries than did unsprayed leaves during the wilting period. Resistance of the foliage to frost injury was apparently decreased by the use of bordeaux mixture while foliage sprayed with liquid lime sulphur,or unsprayed, was more hardy and not as affected by low temperatures.

Experiments conducted in 1925 by McClintock (67) indicated that cherry leaf spot was controlled satisfactorily by thorough applications of bordeaux mixture 2-4-50. No injury or fruit dwarfing was produced. The time and number of sprays was not stated.

It was found in New Jersey (4) that five spray applications are necessary when the disease is severe. Dry mix sulphur-lime 8-4-50 is used in the petal-fall and shuck-fall sprays. Commercial lime sulphur 2½-100 is used in the after-harvest application, in a spray two weeks later and also in the final application three weeks following the fourth spray.

Gloyer (46) observed lesions on the fruit and pedicels of English Morellos, as noted by Dutton (30), and abundant dwarfing of the fruit. The injuries occurred in orchards sprayed with lime-sulphur to which arsenate of lead had been added. Experimental plats were arranged in 1925 in such a manner as to indicate the injuriousness of lime sulphur, lead arsenate, and the two materials applied in combination. It was evident that lead arsenate was the primary cause of the lesions upon the pedicels and fruit and also responsible for a certain amount of fruit dwarfing. Similar injury was noted on trees sprayed commercially with dry lime sulphur, proprietary bordeaux mixture, wettable sulphur, and sulphur dust when each was applied in combination with lead arsenate. Wettable sulphur and sulphur dust, each with arsenate of lead, caused the least injury. The efficiency of the various materials for the control of leaf spot was not determined.

In 1926 Call (17) obtained almost perfect control with a three-spray program of summer strength lime sulphur and bordeaux mixture 3-4-50 while unsprayed branches were severely infected. Although no comparisons of fruit size were made with fruit from unsprayed trees, it was found that Early Richmond and Montmorency fruit sprayed with bordeaux mixture 3-4-50 was larger than lime sulphur treated fruit, while the reverse was true of English Morello sprayed fruit.

Wiggans and Hoppert (102) in 1928 recommended a shuck-fall and a second spray three weeks later using either liquid lime sulphur 1½-100 or dry lime sulphur 4-100. Recommendations included an after-harvest spray of liquid lime sulphur 1½-100 or bordeaux mixture 4-4-50 if infections continue to occur.

Due to the excellent control growers obtained with bordeaux mixture in a severe leaf spot year, Howitt (56) recommended in 1928 that bordeaux mixture be applied at shuck-fall and 10-12 days later. Liquid lime sulphur was advised 10-12 days following the second spray, with the addition of a bordeaux mixture application after harvest, if the season was wet.

Crosby, Mills, and Blauvelt (28) in 1929 recommended liquid lime sulphur 2½-100, dry-mix sulphur-lime 25-100, or a sulphur dust applied at petal-fall, and shuck-fall, followed by two applications timed primarily for the control of the cherry fruit fly. If leaf spot infections continued to occur at harvest, an after-harvest application was advised.

Wilson and Keitt (105) found wide variation from year to year, and from orchard to orchard in regard to the influence of spray materials upon fruit size. Increased weights of Montmorency cherries sprayed with liquid lime sulphur over fruit of the same variety sprayed with bordeaux mixture were as follows: 1924, 15 percent; 1925, 13 percent; 1926, 9 percent; 1927, 16 percent; and, in 1928 the average of four different orchards was 8 percent. Increased weights of fruit sprayed with liquid lime sulphur over cherries sprayed with bordeaux mixture in the four orchards were: Early Richmond, 1 percent, 4 percent, 6 percent, and 8 percent; and on Montmorency, 2 percent, 6 percent, 11 percent and 13 percent. The increase in weights appeared to be correlated with increased weights of the fleshy portion of the cherry since there was small variation in the size of the pits.

In 1931 Talbert and Swartwout (98) obtained better control of leaf spot with bordeaux mixture 3-4-50 than with either Dritomic Sulphur 3-50 or liquid lime sulphur 1½-100. During years in which light infection occurred, no significant difference in control was noted between liquid lime sulphur and bordeaux mixture, although the latter consistently produced smaller fruit during the years in which the experiments were conducted.

As a result of five years' experiments, Young (106) stated in 1929 that bordeaux mixture as weak as 1-3-50 caused severe foliage injury and that sulphur dusts were ineffective. Liquid lime sulphur 2½-100 controlled the disease satisfactorily when the first spray was applied at petal fall. Results also indicated that mild wettable sulphur sprays were more effective than sulphur dusts.

Philip (74) in 1930 stated leaf spot is not considered a serious factor in cherry production in California except in certain sections near the coast. No spray schedule has been developed completely.

In 1930 Elmer (36) stated that bordeaux mixture 4-4-50 and liquid lime sulphur gave equally good control but that the former dwarfed the fruit and caused foliage injury. Recommendations include petal-fall, two-weeks, and after-harvest applications. A four-weeks spray is advised in seasons especially favorable for the development of the disease.

Bliss (13) applied 12 sprays on first year English Morello trees between May 25 and August 14 in 1930. Trees sprayed with bordeaux mixture 4-4-50, with 1 pound of Kayso, averaged considerably better growth than unsprayed trees. Bordeaux mixture with Kayso was considered the best treatment. Kopper's Thylox dust and Niagara Vitidust were as effective as bordeaux mixture without Kayso. Unsatisfactory materials included liquid lime sulphur 2-100 with Kayso, dusting sulphur, Kopper's Ferrox and Nickel dusts, Thylox, Ferrox and Nickel pastes 5-50, and Niagara dry mix and soluble sulphurs 4-50.

Smith (88) in 1930 found bordeaux mixture 6-10-100 superior to either Ferrox flotation 12-100 or Gray flotation sulphur 12-100 applied as four-spray programs. Thylox flotation sulphur was compared with liquid lime sulphur, and both satisfactorily controlled the disease until mid-season, when a certain amount of defoliation occurred.

Gould (48), following Roberts and Pierce (79), in 1932 recommended applications of liquid lime sulphur 1½-50 or bordeaux mixture 3-4-50 at petal-fall, three weeks later, and directly after harvest. Powdered lead arsenate 1-50 or paste 2-50 was advised for insect control.

In 1932 Sherbakoff (87) compared various numbers of applications of bordeaux mixture 2-4-50 with summer strengths of liquid lime sulphur and flotation sulphur. Four sprays of bordeaux mixture, beginning May 1, and repeated every four weeks, gave as satisfactory control as seven sprays of the same material, and better results than seven sprays of liquid lime sulphur. Flotation sulphur was less satisfactory than liquid lime sulphur.

Headlee, Martin, and Farley (52) in 1932 recommended sprays of New Jersey Dry Mix 25-100 or equivalent at shuck-fall, and 10 days later, liquid lime sulphur 2-100 when the fruit begins to color, immediately after the fruit is picked, and 2 to 3 weeks later.

As a result of five years' experiments, Goss (47) found in 1934 that four sprays were advisable in the average year, and that the petal-fall spray was the most important. Very slight differences were obtained when liquid lime sulphur 2½-100 was used in comparison with dry lime sulphur, or when Oxybordeaux or bordeaux mixtures were used in the after-harvest application.

In 1934 Andres (3) obtained adequate control of cherry leaf spot with a three-spray program. A pre-harvest spray of liquid lime sulphur 2½-100 was followed by an after-harvest spray and an additional application four weeks later, each of bordeaux mixture 4-6-50. Bordeaux mixture gave superior control to either liquid lime sulphur or flotation sulphur in experiments conducted in 1931. Flotation pastes 5-50 gave inadequate control. The concentration of flotation sulphur was increased to 7½-50 the following year, and, although the foliage of trees sprayed with this material had the best appearance, foliage sprayed with bordeaux mixture had a much lower percentage of infected leaves. In 1934 malachite green 1-5000 with fishoil emulsion, and the addition of Dutox in the shuck-fall and two-weeks spray gave control equal to that obtained by the use of bordeaux mixture 4-6-50 in the after-harvest spray, preceded by liquid lime sulphur 2½-100.

McNew and Bliss (66) during a four year period tested thirty different spray and dust combinations of Early Richmond, English Morello and Montmorency nursery stock. They reported in 1935 that bordeaux mixture 4-6-50 with spreaders was considered the best material, although it tended to retard growth of the tree. The bordeaux mixture effectively prevented defoliation caused by leaf spot, thus resulting in enough growth to offset the tendency to dwarf the tree. The efficiency of bordeaux mixture was increased when spreaders were added to the spray. Dust treatments, in general, were not as effective as the sprays, although they apparently did not retard the growth of the trees. Kolodust was not effective in wet seasons. Colloidal sulphur, paste, and wettable sulphur were not satisfactory. Sprays applied every 10 to 15 days, beginning when the growth was from 8 to 12 inches in length --- depending upon the weather conditions --- were found to be most effective.

Young (107) stated in 1936 that leaf spot cannot be controlled by wettable sulphurs in Ohio. Thoroughly applied liquid lime sulphur 1-50 or its equivalent in the dry form effectively controlled the disease. Although it was found difficult to determine which of the two sprays caused the least injury, bordeaux mixture is gradually being substituted, due to the dwarfing of the foliage caused by effects of the lime sulphur solution. He further suggested that weaker solutions applied thoroughly and more frequently will probably give adequate control and less injury.

Dutton and Farish (35) in 1936, testing a series of bordeaux mixtures of copper-lime ratio 1:1½ with either high-calcium or dolomitic lime on Montmorencys, found, in a season of deficient rainfall, that the amount of terminal growth decreased as the spray material concentration was increased. They regard this condition due to seasonal variations in available rainfall. The percent of defoliation in a season of deficient rainfall was found in direct proportion to the strength of bordeaux mixture with either lime. The plats sprayed with bordeaux mixture 8-12-100 with either lime retained more leaves than any plat in the respective series of treatments with the exception of the 2-3-100 high-calcium lime bordeaux mixture. They considered this condition to be due to drought condition, accentuated by bordeaux mixture, rather than copper injury. Very little defoliation occurred in a season of adequate rainfall, and no consistent differences between bordeaux mixtures with different lime were noted. Series of bordeaux mixtures with the copper-dolomitic lime ratio 1:½ caused less foliage injury than similar treatments with high-calcium lime. They concluded that the dolomitic lime in bordeaux mixture is superior to or at least equal to the high-calcium lime.

Tests, conducted during a four year period, reported by Keitt, Blodgett, and Magie (61) in 1936 indicated bordeaux mixture to be the most effective spray on replicated Montmorency plats. Very slight difference was found in the size of fruit from plats treated continuously with bordeaux mixture and lime sulphur solution. Annual alternation of bordeaux mixture and liquid lime sulphur sprays produced much larger fruit in the plat sprayed with lime sulphur than in the corresponding plat treated with bordeaux mixture. Control trees, or plats sprayed with liquid lime sulphur that were defoliated just prior to harvest, produced the largest fruit. Cherries from trees defoliated shortly before harvest had a smaller sugar content than fruit from bordeaux mixture sprayed trees which retained their foliage. In certain instances bordeaux mixture apparently caused fruit dwarfing. They considered, however, that the increased fruitfulness following the proper use of bordeaux mixture sufficiently counter-balanced the advantage of liquid lime sulphur, in regard to the fruit size on Montmorency trees.

Rasmussen (75) in 1937 applied two series of bordeaux mixture with high-calcium lime and dolomitic lime to Montmorencys that had received identical treatments for three successive years. Trees sprayed with high-calcium lime lost two to three times the number of leaves per spur that were lost by trees receiving similar treatments with high-magnesium lime bordeaux mixtures. There was no evidence of a consistent correlation between leaf fall and the bordeaux mixture concentration, regardless of the type of lime used. The growth of the tree decreased as the concentration of the spray material increased. The stronger concentrations of bordeaux mixture produced less increase of trunk circumference, and it was found that slightly more growth occurred in plats treated with high-magnesium lime bordeaux mixtures, than in those sprayed with high-calcium lime bordeaux mixtures. High-magnesium lime bordeaux left more copper residue on the foliage than corresponding concentrations of bordeaux mixture with high-calcium lime. Although the trees were not large enough to produce a commercial crop, the higher yields of fruit occurred on the plats sprayed with magnesium-lime bordeaux mixture. The largest fruit was borne on the plats sprayed with the lowest concentrations of bordeaux mixture, this relation being similar with either lime. Stronger concentrations of bordeaux mixture with high calcium lime showed a tendency to produce smaller fruit than equal concentrations of magnesium lime-bordeaux mixture. The percent of total solids of the fruit was correlated with the concentration of bordeaux mixture, i.e. the higher the spray concentration, the higher the percent of total solids. Fruit on the plat sprayed with high magnesium lime-bordeaux was slightly higher in the percent of total solids than that from plats sprayed with equal concentrations of high calcium lime-bordeaux mixture.

In 1937 Keitt, Blodgett, Wilson, and Magie (63), reporting the results of 18 years experiments on the control of cherry leaf spot, stated that no material tested was found equal or superior to bordeaux mixture. Bordeaux mixture 3-4-50 applied at petal-fall, two weeks later, and after harvest, is considered the best recommendation for general use. Liquid lime sulphur 1-40 with the same timing and an additional application two weeks after the second spray is also recommended although it is not considered equal to the bordeaux mixture spray program. Addition of various spreaders and stickers did not increase the effectiveness of either bordeaux mixture or liquid lime sulphur. There were no results that indicated that bordeaux mixture caused commercially significant reduction in the size of the fruit.

The two standard spray materials for the control of cherry leaf spot, bordeaux mixture and liquid lime sulphur, are considered unsatisfactory in certain cherry producing areas. Injury has resulted from the use of bordeaux mixture, and liquid lime sulphur had failed to control the disease adequately. Thus, attention has been attracted to various proprietary insoluble copper compounds recently placed upon the market as substitutes for bordeaux mixture. It has been found that certain of these commercial materials will satisfactorily control the disease and produce less injury than bordeaux mixture.

Mid-season experiments conducted by Cation (20) in 1934 indicated that Cuprocide (red oxide of copper) equalled bordeaux mixture in fungicidal effectiveness. Although the cause was not definitely determined, foliage injury was noted on certain trees sprayed with this compound. The following year various concentrations of Cuprocide and Cupro K (copper oxychloride) were compared with liquid lime sulphur 2½-100 and bordeaux mixture at 4-6-100 and 6-8-100. Just prior to harvest, infections were well established when the only spray of the season was applied. Cupro K 4-100 or 6-100 with or without lead arsenate 2-100 treatments appeared the best at the end of the season. Effects of Cuprocide treatments varied in regard to leaf spot control and amount of foliage injury and appeared to be correlated with the concentration of the material. Bordeaux mixture produced a moderate amount of injury but controlled almost perfectly. Trees sprayed with liquid lime sulphur had very poor control of the disease and were further defoliated than any other sprayed trees. The best plats were those that received sprays of Cuprocide 1-100 with spreader and nicotine, Cupro K 6-100 with lead arsenate 2-100, Cupro K 4-100, and Cupro K 6-100. Continuations of these tests were conducted in 1936. Liquid lime sulphur 2½-100, bordeaux mixture 4-6-100 and 6-8-100, Cupro K 4-100, ZO (copper zeolite) 5-100, Cuprocide 1-100 and Oxybordeaux 6-100 were the materials used. Three pre-harvest sprays, beginning at petal-fall, and repeated at 10 day intervals, were applied. Trees sprayed with liquid lime sulphur were heavily infected, but showed only a light amount of defoliation due to leaf spot. Plats receiving sprays of Oxybordeaux and ZO had a light amount of infection and defoliation.

Trees treated with Cuprocide and bordeaux mixture 6-8-100 showed no infection but had a moderate amount of defoliation caused by injury. Neither bordeaux mixture 4-6-100 or Cupro K sprayed plats showed infection, but the former had a heavy defoliation due to injury, while the latter had a light amount of injury. Cupro K, from the bases of leaf spot control and spray injury, was considered the best material tested. Evaluations of single sprays applied after infection were well established, placing Cupro K 5-100 considerably above Oxybordeaux 8-100, Cuprocide 1½-100, ZO 5-100, lime sulphur 2½-100, and bordeaux mixture 6-8-100.

In 1937 additional experiments were conducted by Cation (20) and Rasmussen (77) with Cupro K 3-100, Cuprocide 1-100, Oxybordeaux 6-100, ZO 3-100, liquid lime sulphur 2½-100, and bordeaux mixture 6-8-100. Three pre-harvest sprays were applied. No leaf spot infection occurred on foliage sprayed with Cuprocide or bordeaux mixture, although the latter showed severe defoliation due to spray injury. Curpocide treated trees also had a light defoliation due to injury to the foliage. Leaf spot infection and resultant defoliation was severe in plats treated with Oxybordeaux, ZO, and liquid lime sulphur. Cupro K sprayed trees showed the least amount of defoliation, although a small amount of injury was noted, and a light infection of leaf spot occurred, the latter part of the season.

To determine the effect of spray materials on the fruit and tree, Rasmussen (77) in 1937 applied liquid lime sulphur 2½-100 and certain concentrations of high-calcium and high-magnesium lime bordeaux mixtures to plats of Montmorencys which had received previously identical treatments for three consecutive years. In addition, ZO 4-100, Cupro K 4-100, Cuprocide 1-100, Oxybordeaux 8-100, and a combination of bordeaux mixture 3-4-100 and Kopper's dry flotation sulphur 2½-100 were tested. Arsenate of lead 2-100 was included in all pre-harvest sprays. Three pre-harvest and one after-harvest sprays were applied. No leaf spot lesions were noted in any of the plats. Severe size reduction of fruit occurred on trees treated with 4-6-100 and 6-8-100 bordeaux mixture. The percentage of solids was smaller and the pits were larger in fruit from trees sprayed with liquid lime sulphur. The difference in size of pits was not considered significant. A greater increase in trunk circumference, superior retention of foliage, increased shoot growth, and a larger total yield of cherries occurred in plats sprayed with liquid lime sulphur than in plats treated with high-calcium bordeaux mixture. The 6-8-100 bordeaux mixture was more injurious than lower bordeaux concentrations. Bordeaux mixture with 4 pounds of copper sulphate showed no consistent correlation between the effect of the spray upon the fruit and tree and different amounts of lime. Cuprocide caused excessive foliage injury. Other proprietary copper compounds were less toxic than bordeaux mixture and were as efficient as liquid lime sulphur in regard to leaf spot control and the amount of spray injury. Cupro K sprayed plats showed more defoliation than plats treated with either ZO or Oxybordeaux. Cupro K sprayed foliage had much greater amounts of copper residue than either ZO or Oxybordeaux.

It was found in Ohio (108) that the insoluble copper compounds are generally less effective than bordeaux mixture in controlling leaf spot and somewhat less injurious to the foliage and fruit. Cupro K, Basicop (basic copper sulphate), and Coposil (copper ammonium silicate), were tested at the company recommendations. The proprietary materials tested in 1937 controlled the disease better than any other material and caused very little injury. Liquid lime sulphur 1½-100, dry lime sulphur 6-100, or proprietary copper compounds are recommended for the shuck-fall application, 2 to 3 weeks spray, and a third spray when the fruits begin to color. An after-harvest spray of lime sulphur 1½-100, or dry lime sulphur 6-100 is also advised; none of the insoluble proprietary copper compounds are recommended for the fourth spray.

To determine the efficiency of various proprietary copper compounds, Cation (19, 21) and Rasmussen (76, 21) conducted experiments using a four-spray program on the Montmorency variety of sour cherry in 1937. Basicop-lime 3-8-100, bordeaux mixture 3-4-100, Bordow 6-100, Coposil 3-100, Grasselli copper oxychloride 1½-100, and Cupro K 3-100 satisfactorily controlled the disease and did not cause significant amounts of foliage injury. ZO 3-100, Oxybordeaux 6-100, Basicop-lime 1½-1-100, and Copper Hydro '40' 3-100, although superior to liquid lime sulphur 2½-100 treatments, did not give satisfactory control of leaf spot. No appreciable dwarfing of the fruit was caused by any of the proprietary copper compounds.

Kadow and Anderson (57, 2) tested various proprietary copper compounds on Montmorency, Early Richmond, and Dyehouse varieties of sour cherries, using a four-spray program. They found that Bordeaux '34'-zinc sulphate-lime 1½-½-½-100, Cupro K 2-100, and liquid lime sulphur 2-100 adequately controlled leaf spot and did not cause significant amounts of foliage injury. Copper Hydro '40', Coposil, Basicop, Cuprocide 54, and a Niagara copper compound satisfactorily controlled the disease but caused considerable spray injury to the foliage.

Sprays applied by Hamilton (50) in 1938 on Montmorencys consisted of petal-fall, shuck-fall, and after-harvest applications. These sprays were supplemented by two cherry fruit fly sprays, approximately a month before harvest. The sulphur compounds were generally ineffective in control of leaf spot. The most effective sulphur spray was Kopper's flotation paste 10-100 used with Orthex (oil sticker). Flotation sulphur 10-100, liquid lime sulphur with goulac and lime, liquid lime sulphur 1-100 with Catalytic Sulphur 4-100, Magnetic Sulphur 6-100 with soybean flour ½-100, and Kolofog 6-100, did not give satisfactory control. Results indicated that the sulphur materials are more effective if leaf spot is not allowed to become established. Although foliage injury occurred, perfect control was obtained in plats sprayed with both calcium and magnesium lime bordeaux mixtures at 3-4½-100 and 6-9-100. Trees, sprayed with magnesium lime bordeaux mixture, retained their foliage slightly longer than those sprayed with calcium lime bordeaux, although not enough to be considered of commercial significance. Delayed maturation and an approximate 25 percent reduction in size of the fruit occurred on fruit sprayed with bordeaux mixture. Bordeaux mixture 6-9-100 produced smaller fruit than the 3-4½-100 concentration. Both strengths of magnesium lime bordeaux mixture caused smaller fruit than the calcium lime bordeaux mixtures. It was found that the fruit size was almost normal when Orthex was added to the 3-4½-100 bordeaux mixture. Omission of one or more applications of bordeaux mixture caused no significant difference in fruit size or time of fruit maturation. He stated that copper injury, which may occur within three weeks after an application of bordeaux mixture, was largely prevented in the pre-harvest period by repeated applications of the spray. Sprays of lime applied as foliage injury first appeared, prevented the yellowing and defoliation. He also stated that lower concentrations of bordeaux mixture, within certain limits, produce more foliage injury, due to greater ionization of the copper --- there being less ionization in higher concentrations. Although bordeaux mixture is not advised as a pre-harvest spray except in severe epidemics of leaf spot, recommendations include bordeaux mixture 3-6-100 with one pint of Orthex, rather than higher concentrations.

Hamilton (50) also found in 1938 that the proprietary copper compounds used with lime and Orthex controlled leaf spot better than the sulphurs, caused little foliage injury, and showed no evidence of fruit dwarfing. Cupro K 3-100 and Coposil 3-100, each with 3 pounds of lime and one pint of Orthex, were the two best insoluble copper sprays tested. Addition of Orthex to the materials reduced the amount of defoliation 50 percent and also the amount of infection. He stated that increased effectiveness of a spray with Orthex was not wholly due to better adhesion but, in part, to superior spreading of the material. The addition of one pound of lime for each pound of 20-25 percent copper was found essential. As the amount of lime used with Coposil was increased, the copper deposited per unit of leaf area decreased. If applied on an equal copper basis, Micronized Copper showed greater adhesion but also caused more foliage injury than the other copper compounds. Cuprocide-lime 1-1-100 with one pint of Orthex gave better leaf spot control but produced more foliage injury than the other materials tested.

Daines (29) in 1939 tested liquid lime sulphur, liquid lime sulphur in combination with aluminum sulphate and lime, wettable sulphur, wettable sulphur with Orthex, bordeaux mixture 1-3-50 and 2-3-50 with magnesium and calcium limes, bordeaux mixture with metallic zinc, home-made and commercial copper phosphate with and without bentonite, Coposil with and without Orthex, ZO, Cupro K. Oxybordeaux, Basicop, Copper-Hydro 40, '34' with zinc sulphate, Cuprocide 54, and aluminum sulphate with lime. The proprietary copper compounds were used with and without lime. The copper materials more effectively controlled leaf spot than the sulphur materials. Bordeaux mixture at all concentrations caused injury to the cherries. Certain insoluble copper compounds caused injury when used without lime. The fungicidal efficiency of the copper sprays was generally correlated with the adhesive properities of the material. Aluminum sulphate with lime and liquid lime sulphur was more effective than liquid lime sulphur used alone. Wettable sulphurs with Orthex gave superior control to wettable sulphur alone. He further stated that the lack of injury in certain cases was probably due to poor adhesion.

Keitt and Clayton (64) found in 1939 that bordeaux mixture in any concentration gave control superior to other materials tested. However, the trees sprayed with bordeaux mixture also bore the smallest fruit. The plat sprayed with basicop-lime 3-8-100, of the plats treated with proprietary copper compounds, had the least defoliation. Coposil-lime 2-4-100 with Orthex 1-400 was superior to Cupro K 3-6-100. Liquid lime sulphur 1-40 was superior to Coposil. The unsprayed control trees bore the largest fruit, and no significant difference was found in fruit size between any of the insoluble proprietary copper compounds.

Rasmussen (78), in comparative four-spray program tests on Montmorencys, found in 1938 that Basicop-lime 3-8-100, Bordow 6-100, Grasselli Compound A 1½-100 with one pint Orthex, and bordeaux mixtures 3-4-100 and 6-8-100 gave excellent control. Tennessee 26-lime 3-3-100, bordeaux mixture 2-3-100, Coposil-lime 3-3-100, and Bordeaux 34-lime 2½-3-100 gave good control; Cupro K-lime 3-3-100 and liquid lime sulphur 2½-100 gave only fair control. All the proprietary copper compounds caused slight amounts of injury to the foliage, and Grasselli Compound A produced severe injury. Bordeaux mixtures 3-4-100 and 6-8-100 caused moderate amounts of foliage injury.

Hamilton (51) reported in 1939 that liquid lime sulphur reduced the fruit set of English Morellos and also caused severe foliage injury. Tests indicated flotation sulphur paste 8-100, with one pint of Orthex, to be the most effective of the sulphur combinations used. Flotox 5-100, with one pint of Orthex, gave superior leaf spot control to liquid lime sulphur. In a season of light rainfall, copper compounds applied on equivalent copper bases, with or without Orthex or spreader-sticker, produced excellent leaf spot control. Cupro K was the safest copper material when used alone. He found after-harvest applications of lime checked injury on sweet cherries. Grasselli Copper Compound A. with lime gave comparatively satisfactory results, but its effectiveness was not definitely determined. Basicop, Copsil, Cuprocide, and '26' controlled leaf spot almost as effectively as Cupro K, but caused some foliage injury. The best bordeaux combination was 3-6-100 with one pint of Orthex, but it caused too much foliage injury and dwarfed the fruit too severely to be recommended unless applied very lightly. Results indicated that bordeaux mixture applications, alternated with 10-100 lime, may be a desirable schedule. Bordeaux mixture, alternated with Cupro K, also appeared promising --- especially under severe leaf spot conditions. Recommendations include Orthex in the regular copper sprays and lime in the after-harvest spray to check injury, especially if recent pre-harvest sprays omitted lime. An after-harvest spray of lime is advised if no leaf spot is present. Cuprocide applied just before harvest leaves no residue, and the lime application applied after harvest effectively checks the foliage injury.

THE PROBLEM

The purpose of this study was to determine the value of Basicop* and certain other compounds as spray materials for cherries in Michigan. Experiments were planned to study the fungicidal effectiveness of the materials on the pathogene causing cherry leaf spot (<u>Coccomyces hiemalis</u> Higgins) and also to determine their physiological effects upon the cherry fruit and foliage.

*Basicop is a proprietary copper compound manufactured by the Sherwin-Williams Company, Cleveland, Ohio. It is a powdered form of basic copper sulphate, the formula of which may be considered as $CuSO_4 \cdot 2Cu(OH)_2$. The pure commercial product contains approximately 53.8 percent metallic copper. The average of the market output of Basicop, however, contains 50 to 52 percent metallic copper, this may be the result of a slight lack of balance in the proportion of basic and acid copper molecules or perhaps some little water of crystallization or combined moisture.

EXPERIMENTAL PROCEDURE

Roach Orchards, Hart, Michigan, 1937

Materials and methods

Fifteen year old vigorously growing trees of the Montmorency variety of sour cherry were selected for experimental purposes at the Roach Orchards, Hart, Michigan. The block of approximately 192 trees, 32 trees long and 6 wide, was divided into 16 plats of 12 trees each and arranged 3 trees wide by 4 trees long. This block was fairly uniform in size and vigor of trees, and all trees had received similar cultural and spray treatments in previous years. It was originally planned to have the plats consist of 12 trees but occasional dead or dying trees --- due to winter-injury and Armillaria root rot (*Armillaria mellea*) --- and a few young, non-bearing trees were scattered throughout the orchard. Data were, therefore, taken on all representative vigorous, mature trees in each plat.

The spray materials teeted were: two proprietary copper compounds, Basicop and Cupro K, two concentrations of bordeaux mixture, several sulphur sprays, and liquid lime sulphur. Dolomitic lime was used in the combinations requiring lime because certain experimental results (35, 75) have indicated that magnesium lime is superior to high calcium lime in bordeaux mixture. Lead arsenate was used in the two-weeks and four-weeks applications with all materials at the concentration of 3 and 2 pounds, respectively, to one hundred gallons of water. The materials and concentrations tested are presented in Table 1.

The recommended four-spray program of Michigan which consists of three pre-harvest and one after-harvest sprays was adopted in the experiment. As shown in the rainfall and spray chart (Figure 1), the petal-fall spray was applied May 30-31, the two-weeks spray on June 15-16, the four-weeks application on June 26-27, and the after-harvest application on August 7-8. In order to determine the effect of a three-spray program on the control of leaf spot and the amount of spray injury, the plats treated with Basicop-lime 3-8-100, Cupro K 3-100, Cupro K 6-100, bordeaux mixture 3-4-100, and bordeaux mixture 6-8-100 were divided into two portions of approximately six trees each for the after-harvest sprays. One-half of each plat was given the regular after-harvest spray while the other half received no application. In addition, three unsprayed control trees were maintained throughout the season.

Each spray was carefully and thoroughly applied from the ground with a single nozzle gun and each tree was completely sprayed before beginning another. Between 5 and 8 gallons of spray per tree were applied and, as a result of this overspraying, a certain amount of drip occurred. A pressure of 400 to 450 pounds was maintained in all sprays. Two days were necessary to complete the entire series of applications.

Epidemiological conditions

The Roach Orchard in 1936 received four pre-harvest sprays of liquid lime sulphur 3-100. Cation (20) reported that a great deal of leaf spot infection occurred in this orchard during the late August and early September rains and that the trees were almost wholly defoliated by leaf spot on October 9. These late infections of 1936 resulted in an abundance of ascosporic inoculum in the spring of 1937 as evidenced by examinations of the old leaves. Microscopical examination and forced ascospore discharge in the laboratory from apothecia collected on leaves during the first week of May revealed that the ascospores were mature and ready to be discharged upon the occurrence of favorable moisture and temperature relations.

The growing season of 1937 was especially favorable for the development of cherry leaf spot in epiphytotic form. Rains occurred about every ten days (Figure 1) throughout the season. After the latter part of June, yellowing of the leaves and resultant defoliation appeared approximately ten days after each rain in which infections occurred on trees not properly protected. A light primary infection may have occurred on May 16, although the foliage was not far advanced. Observations indicated that the first serious ascosporic infections did not occur until the rain of May 21 (Figure 1). Additional primary infection occurred May 28 and possibly some secondary, since sparsely scattered mature acervuli were noted May 29. The first significant secondary infection occurred June 5 and was followed by abundant infections during the frequent rainy periods throughout the remainder of the season. Defoliations due to leaf spot were first noted June 26 and continued to occur at frequent intervals until the latter part of September.

Results

Conditions during 1937 were particularily advantageous for the evaluation of fungicides due to the severity and frequency of leaf spot attacks and, also, due to the opportunities offered to observe the physiological effects of the spray materials on the fruit and foliage.

The earliest determination of comparative infection was made June 23 (Table 2). The infected leaves showed from one to five lesions per leaf, and no attempt was made to differentiate between leaves lightly or heavily infected. Examination of these data show that, regardless of the spray materials used, infections were well established on all plats. Foliage sprayed with copper materials showed a tendency towards less infection than foliage treated with the sulphur compounds. The percentages of infection do not necessarily indicate the amount of defoliation due to leaf spot that occurred on the plats later in the season. The copper sprays almost completely checked defoliation due to leaf spot and also checked further infection while the disease was never satisfactorily controlled by the sulphur sprays.

Data presented in Table 3, almost a month prior to harvest, show that leaf spot had caused almost no defoliation in the majority of the plats sprayed with copper materials. There was a slight loss of foliage in plats treated with Basicop-lime 3-1-100, Basicop-lime 1½-4-100, and Cupro K 3-100 but not sufficient to be considered commercially significant. Very poor control was evident in plats sprayed with the sulphur compounds. Dry lime sulphur 10-100 and liquid lime sulphur 2½-100 gave superior disease control to the other sulphur materials tested, although not equal to any of the copper compounds. The remainder of the sulphur sprayed plats showed almost no control and were comparable to the unsprayed check trees.

Comparative determinations of the amount of spray injury to the foliage in the different plats were made June 30 (Table 3). Plats sprayed with the sulphur materials showed no evidence of yellowing, burning or defoliation due to spray injury. Foliage sprayed with dry lime sulphur and 325 mesh sulphur 2-4-100, dry lime sulphur 4-100, and Electric sulphur 4-100 appeared to be slightly larger than that of the plat sprayed with liquid lime sulphur 2½-100. This effect was soon lost, however, due to the tremendous defoliation caused by leaf spot. Spray injury was not evident in plats treated with bordeaux mixture 3-4-100 or 6-8-100, Basicop-lime 3-8-100, or Basicop-lime 1½-4-100. Light defoliation due to spray injury was noted in plats treated with Basicop-lime 3-1-100, Basicop 1½-100, Cupro K 6-100, and Cupro K 3-100.

Mid-season observations also indicated, as shown in Table 3, that the foliage of trees sprayed with Basicop-lime 3-8-100, bordeaux mixture 3-4-100, and bordeaux mixture 6-8-100 was excellent in appearance, the leaves being broad, flat and deep green in color, showing no evidence of chlorosis. However, trees sprayed with any of the remaining copper treatments had a few yellow leaves scattered throughout the foliage. The greater percentage of the leaves of unsprayed control trees and of trees sprayed with the sulphur compounds was distinctly yellow in color and showed very little evidence of disease control.

Copper materials gave superior disease control to the sulphur materials throughout the season. No defoliation caused by leaf spot occurred on the plats treated with Basicop-lime 3-8-100, Basicop 3-100, Basicop 1½-100, Cupro K 6-100, bordeaux mixture 6-8-100, or bordeaux mixture 3-4-100. Traces of defoliation caused by the disease were noted on plats sprayed with Cupro K 3-100 and Basicop-lime 3-1-100 while the weaker concentrations of Basicop and Basicop-lime, 1½-100 and 1½-4-100 respectively, showed light defoliations.

Observations throughout the season served to emphasize the general ineffectiveness of the sulphur compounds as compared to the high relative efficiency of the copper compounds in controlling leaf spot. Losses of foliage continued to occur shortly after each rain in the sulphur sprayed plats and, by the harvest period, the majority of the trees were almost completely defoliated. Consequently, the sulphur treatments were abandoned in the after-harvest applications, and Basicop-lime 2-3-100 substituted. This spray preserved the small amount of foliage left and also protected the secondary leaves that were beginning to appear.

Several light waves of yellowing and defoliation due to spray injury occurred in the majority of the plats treated with the copper materials. Defoliation on the plats treated with bordeaux mixture did not occur until a month following the after-harvest applications while the injury on the plats sprayed with the proprietary copper combinations occurred at periodic intervals after June 30. The copper sprayed plats presented, quite generally, an excellent appearance after the injured leaves were dropped, although when they were on the trees the plats showed an unnatural yellow color. It was found that many light defoliations, due either to leaf spot or spray injury, might be overlooked unless observations were made upon the condition of each plat every two or three days.

One main criterion for evaluating the fungicides in relation to efficiency in controlling the disease and also in relation to the injurious effects to the foliage, is the percent of defoliation in each plat at the end of the season. The data on the final comparative defoliation are presented in Table 4.

Both leaf spot and spray injury were responsible for the defoliation that occurred in plats sprayed with Basicop 1½-100 and Basicop-lime 1½-4-100. The determining factor of defoliation in the remainder of the copper sprayed plats was spray injury. As shown in these data, it is apparent that the addition of lime to Basicop prevents much of the spray injury to the foliage. Basicop and lime 3-8-100 gave results superior to Basicop 3-100 without lime. The addition of one pound of lime to 3 pounds of Basicop was insufficient to correct spray injury. Three pounds of Basicop satisfactorily controlled the disease regardless of the addition of one or 8 pounds of lime. Any benefit obtained from the addition of 4 pounds of lime to Basicop 1½-100 was not determined since leaf spot was largely the causal agent of defoliation. It seemed apparent, however, that the addition of lime slightly decreased the toxicity of low concentrations of Basicop. Rasmussen (78) obtained similar results with Cupro K. Cupro K at concentrations of 3-100 or 6-100 adequately controlled the disease but caused considerable spray injury to the foliage. Dry lime sulphur 10-100 and liquid lime sulphur 2½-100 gave very poor control of the disease. The defoliation of the remainder of the sulphur treated plats was so complete that records were not taken. The percent of defoliation of plats sprayed with dry lime sulphur 4-100, dry lime sulphur with 325 mesh dusting sulphur 2-4-100, Electric sulphur 4-100, liquid lime sulphur 1-100, and liquid lime sulphur with Electric sulphur 1-4-100 was arbitrarily estimated at 98 percent. Much of the defoliation on the sulphur sprayed plats was due apparently to poor adhesion of the materials during rainy periods. This condition was particularly evident in the six-week interval between the four-week and after-harvest applications.

It will be noted from comparisons between early infections (Table 2) and defoliations at the end of the season (Table 4), that the percent of defoliation recorded for the sulphur sprayed plats and the unsprayed control trees on September 25 corresponds to the percent of leaf spot infection determined on June 23. However, apparent similarities between the percentages of defoliation and leaf spot infection on the copper sprayed plats can not be correlated since the defoliation was caused by spray injury in the majority of the plats, and not by leaf spot.

Plats sprayed with Basicop and lime at 3-8-100, bordeaux mixture 3-4-100, and bordeaux mixture 6-8-100 applied as three-spray programs, had more defoliation than when given four-spray programs (Table 4). Leaf spot and spray injury were responsible for the loss of foliage in the plat receiving sprays of Basicop 3-8-100. Defoliation in the plats treated with bordeaux mixture was caused only by spray injury. Three applications of Cupro K 3-100 or 6-100 resulted in less defoliation than four sprays of either concentration. The defoliation in each of these instances was caused by spray injury.

Effects of a pre-bloom spray of liquid lime sulphur in 1937

Growers using the liquid lime sulphur spray schedule have offered the observation that an additional spray applied in the pre-bloom period has given better control of leaf spot than the regular four spray schedule which begins with a petal-fall application. Experimental evidence is controversial on the value of a pre-bloom spray (53, 58, 60, 80).

An experiment was undertaken to determine the effect of 5 sprays of liquid lime sulphur (including a pre-bloom application) compared with a four-spray schedule (no pre-bloom application) of the same material. In arranging the plats in duplicate, it happened that the trees in two of the adjacent plats receiving the different spray treatments had received copper sprays the previous year while the other two comparative plats had received liquid lime sulphur sprays. The copper sprays controlled leaf spot excellently the year previous while the liquid lime sulphur sprays gave poor control. Consequently, there was a tremendous difference in the amount of ascosporic inoculum beneath the trees according to the treatment of the previous year. Examination of over-wintered leaves showed (Table 5) that apothecia were scarce under trees that had excellent control. Mature apothecia were abundant in the section of the orchard where control was poor in 1936.

Comparative determinations of leaf spot infection were made on June 23. Reference to the data presented in Table 5 shows that the plat, number 16, receiving the pre-bloom spray had only 2.65 percent of the leaves infected while the plat immediately adjacent, number 17, which received the first spray at petal-fall, had 61 percent of the leaves infected. Fifty-eight percent of the leaves were infected in plat 42 which also received the first spray at petal-fall.

Although no numerical determinations of the amount of infection were made on plats 1 and 2, it is significant that correspondingly less infection was found in plats 1 and 2 than in plats 16 and 17. The difference may be explained by the lack of initial inoculum in the former plats, due to effective spray treatments the previous year. Keitt has obtained similar results with the elimination of initial inoculum by early spring cultivation (58) and the use of eradicative sprays (62).

The results in one instance of the experiment show that the inoculum immediately beneath each tree was the determining factor in the resulting amount of infection and that the amount of lateral dissemination of inoculum which may have occurred was insignificant. The trees of plats 1 and 2, under which there were few apothecia, were separated in one direction by only a single row from trees that were liberally infected with leaf spot and under which there wan an abundance of initial inoculum. A block of severely infected trees which also had an abundance of ascosporic inoculum was separated by a narrow roadway from another end of the experimental plats. In spite of the proximity of abundant inoculum, the trees of plats 1 and 2 maintained significantly little infection until the six-week interval between the four-week spray and the after-harvest application.

Until shortly before the harvest period, the plats that received the pre-bloom sprays showed less infection and defoliation than the corresponding adjacent plats that received the first spray at petal-fall. Thus, plat 1 was superior to plat 2 in the low inoculum area, and plat 16 appeared definitely superior to plat 17 in the high inoculum area. However, the differences became less apparent later in the season and very little difference could be noted in the comparative amounts of control between the pre-bloom and petal-fall spray schedules in adjacent plats. This condition was not especially marked in the high inoculum area since plat 1 retained more foliage than plat 2. Observations indicated that the effectiveness of pre-bloom applications of liquid lime sulphur in seasons of abundant rainfall is lost during the late summer and early fall and, also, in the six-week interval between the four-week spray and the after-harvest application.

The percentages of defoliation taken September 25-26 (Table 5) show that plats receiving the pre-blossom spray had slightly superior control to the adjacent plats that received the regular four-spray program of liquid lime sulphur. The amount of initial inoculum present governed, to a certain extent, the amount of defoliation that occurred by the end of the season. Plats in which there was a scarcity of primary inoculum retained distinctly more foliage than plats in which apothecia were abundant.

Comparisons of the defoliation and infection data (Table 5) show that the percentages of infection do not indicate the amount of final defoliation. This is due, in part, to the loss of protective action of the spray materials during rainy periods. It is also apparent from the data presented in Table 5 and Figure 1 that the applications of the four-spray programs were not well timed in regard to the rains to produce the highest degree of control with liquid lime sulphur.

Relations of fungicides to the size of fruit.

Many investigators recognize that spray materials may affect cherry fruit size. To determine the effect of the various sprays on the size of the fruit, 25 cherries were similarily selected and picked from each quarter of the tops of 6 representative trees in each plat. One-hundred cherries were selected from each tree, making a total of 600 cherries used in the fruit size determination of a plat. The comparative fruit size determinations are presented in Table 6.

Plats that had considerable defoliation just prior to harvest bore the largest sized fruit. Keitt, et al. (63) found that defoliation before harvest sometimes resulted in such an increase in size. Many investigators (16, 17, 29, 32, 33, 41, 46, 50, 61, 63, 64, 75, 77, 105) have noted definite dwarfing of the fruit on trees sprayed with certain fungicides. This reduction in fruit size was readily detected by casual observation in the plat sprayed with bordeaux mixture 6-8-100. Fruit from the plat treated with bordeaux mixture 3-4-100 was small but the reduction in size was not as pronounced as with the stronger concentration. Although, in one instance as much lime was used as in bordeaux mixture 6-8-100, fruit of trees sprayed with Basicop or Basicop and lime compared favorably in size with that from trees sprayed with either liquid lime sulphur or other copper compounds. Cherries from trees sprayed with either Basicop, Basicop-lime, or Cupro K were wuperior in size to that from the plats sprayed with bordeaux mixture 6-8-100 or bordeaux misture 3-4-100.

Residual copper on foliage.

The amount of copper residue on the foliage was determined for each plat at the end of the season. A disk, one centimeter square, was punched near the mid-rib from the center of each leaf. Analyses were based upon 100 disks from each plat. As is shown in the data presented in Table 7, plats receiving four sprays retained a greater amount of residual copper in each instance than plats given three sprays of the same material and concentration. Foliage treated with four sprays of bordeaux mixture 6-8-100 retained distinctly more copper than leaves receiving any other treatment. The data indicate that bordeaux mixture 6-8-100 or 3-4-100 used either in a four-spray or three-spray program has superior adhesive qualities to most of the concentrations of Basicop tested. Similar results have been reported by Wilson (104) and McCallan and Wilcoxon (65). The data also indicate that the addition of lime to Basicop did not materially affect the weather resisting qualities of the fungicide. The amounts of copper deposit show that Cupro K (20 to 25 percent metallic copper) adheres to the foliage better than Basicop when the two materials are applied at equal copper content concentrations. McCallan and Wilcoxon (65) have also pointed this out. Since no direct correlation can be drawn between the amount of residual copper and the amount of defoliation due to spray injury, it appears that the chemical character of the residual copper complex may be the determining factor in the amount of defoliation.

Field Orchard, Shelby, Michigan, 1937

Materials and methods

A block of 54 Montmorency trees approximately twenty years old was used in an experiment at the Field Orchard, Shelby, Michigan. The trees were large and closely planted with the majority of the foliage in the tops. Three plats of 18 trees each received three pre-harvest and one after-harvest sprays. The petal-fall spray was applied June 1, the two-week application June 16, the four-week and after-harvest sprays on June 28 and August 13, respectively. The spray materials used were Basicop-lime 3-1-100, Cupro K 6-100, and liquid lime sulphur 2½-100. Lead arsenate was added in the two-week and four-week applications at the rate of 2 and 3 pounds, respectively, to 100 gallons of water.

Results

The orchard was clean cultivated during the early part of the spring, and, as a consequence, infections became relatively heavy only throughout the latter part of the season. Defoliation due to leaf spot began to occur August 12 on the trees sprayed with liquid lime sulphur. No loss of foliage caused by the disease was found during the season in the plats treated with the copper materials.

Several light defoliations caused by spray injury occurred in the plats sprayed with Basicop-lime and Cupro K, the first leaf fall occurring July 13. Despite these defoliations, the two plats presented a much better appearance at the end of the season than did the plat sprayed with liquid lime sulphur. The actual percentage of defoliation was not determined.

Twenty-five cherries were picked from each quarter of the tops of 12 to 15 representative trees in a plat to determine the effect of the sprays on the size of the fruit. As shown in Table 8, no appreciable difference in the size of the fruit from the three plats could be determined.

McClary Orchard, Empire, Michigan, 1937

Materials and methods

Three plats of approximately 60 trees of the variety Montmorency were selected at the McClary Orchard, Empire, Michigan. Basicop and lime 2-1-100, bordeaux mixture 4-5-100, and Cupro K 4-100 were the materials used. The petal-fall spray was applied June 4, the two-week and four-week sprays on June 18 and 30, respectively. Lead arsenate 3-100 was added to the materials in the second and third sprays. The plat sprayed with bordeaux mixture 4-5-100 did not receive a four-week spray. All plats were dusted with sulphur to prevent brown rot infections following the severe windstorm of July 25.

Results

Initial inoculum was almost absent since bordeaux mixture had given excellent control the previous year. Leaf spot infection was so slight that records of the comparative control value of the different spray mixtures were not obtained.

Although the experimental plats were not under continuous observation, a light defoliation due to spray injury was noted August 8. As shown in Table 9, the plat sprayed with Cupro K showed conspicuously more injury than did the plats treated with Basicop-lime or bordeaux mixture. This injury was observed two weeks after the windstorm. If the defoliations were considered as a result of soluble copper entering wind-bruised leaves, the lack of injury on the plat sprayed with Basicop might be attributed to a more sheltered position. This condition was not true, however, for the plat treated with bordeaux mixture. Further, the remainder of the 90 acre cherry orchard was sprayed with Basicop-lime 3-6-100 and showed little injury. Only slight defoliation was apparent from casual observation on any of the plats, even as late as October 13. The percentages of defoliation were not obtained.

To determine the effect of the sprays on the size of fruit, 100 cherries were selected at random from 24 filled lugs. Each lug that was sampled was taken from a representative tree of each treatment. The weights of 2,400 cherries were determined for each sprayed plat. Only six lugs were sampled from the control tree. The results presented in Table 10 are significant in that no dwarfing due to bordeaux mixture could be ascertained. This is at variance with the results obtained at the Roach Orchard previously noted in this paper and with results published by other investigators where three pre-harvest sprays were applied. Keitt's, et al., results (63) indicate the dwarfing effect of bordeaux mixture to be slight, but his records were taken from trees receiving two pre-harvest sprays. As the third bordeaux spray was omitted at the McClary Orchard and as no fruit dwarfing could be detected, the results naturally suggest that the third spray is responsible for the dwarfing effect on fruit sprayed with bordeaux mixture. Similar results have been reported by several Michigan cherry growers who consistently use only two pre-harvest sprays of bordeaux mixture and who stated they found no reduction of fruit size resulting from that procedure. Cherries from the unsprayed control tree were much larger than fruit from any of the sprayed plats. Fruit sprayed with Cupro K was the smallest and there was little difference in the size of fruit treated with either bordeaux mixture or Basicop and lime.

Smith Orchard, Omena, Michigan, 1937

Materials and methods

Three plats of Montmorency trees, ranging in size from 39 to 84 trees, were selected at the Smith Orchard, Omena, Michigan. The petal-fall spray was applied June 3, the two-week spray June 18, and the four-week application on June 30. Basicop and lime 1½-1-100, Cupro K 3-100, and liquid lime sulphur 2½-100 were the materials tested. Lead arsenate 3-100 was added to the two-week and four-week sprays.

Results

No leaf spot infection was noted even on the unsprayed control tree since the season was abnormally dry at Omena. The plat treated with liquid lime sulphur appeared to be superior to the trees sprayed with either Basicop-lime or Cupro K. However, the differences between the appearance of the treatments was so slight that no defoliation percentages were determined.

Cherry size determinations of fruit from 18 to 20 representative trees in each plat were taken. Approximately 100 cherries were picked at random from each tree. The cherries from the trees sprayed with copper were smaller than those from trees sprayed with lime sulphur, as shown in Table 11.

Roach Orchard, Hart, Michigan, 1938

Materials and methods

Approximately 280 nine year old Montmorency trees were chosen for experimental pruposes at the Roach Orchard, Hart, Michigan. The block was arranged 32 trees long by 9 wide. Each of the 33 plats consisted of 6 to 12 trees. The trees were planted in sandy loam but were not exceedingly vigorous due to defoliations the previous two years.

As shown in Table 12, the materials used were: certain concentrations of Basicop, Basicop-borax, Basicop-iron sulphate-lime, Basicop-lime, Basicop-magnesium hydroxide, Basicop-zinc sulphate-lime, bordeaux mixture, copper arsenate,* copper arsenate-lime, Cupro K, Fungibordo (a proprietary dry bordeaux mixture manufactured by the Sherwin-Williams Company, Cleveland, Ohio), and liquid lime sulphur. In addition, one plat received applications of only lead arsenate. Unless otherwise indicated, high-calcium lime was used in all combinations requiring lime. Lead arsenate 2-100 was added to all materials in the two-week and four-week applications with the exceptions of the plats sprayed with copper arsenate or copper arsenate-lime.

The standard spray program for cherries in Michigan was used for most of the experimental plats. The petal-fall sprays were applied on May 10 and 22. Due to a delay in shipment of certain materials, all the plats did not receive the early sprays on the same dates (Table 12). The two-week sprays were applied May 27, 28, 30, and June 6, while the four-week applications were made June 16, 17, and 20. After-harvest sprays were applied August 6 and 7. In an effort to determine the dwarfing effect of the four-week spray of bordeaux mixture, certain plats treated with bordeaux received only two pre-harvest and one after-harvest spray. One plat sprayed with Basicop-lime 3-6-100 also received only the petal-fall, two-week, and after-harvest spray. Three unsprayed control trees were included in the experiment.

Methods of spray application were comparable to those of the 1937 experiments at the Roach Orchards. The trees were thoroughly sprayed until drip appeared. Each tree received an average of 5 gallons of spray material per application. Each spray was applied with a pressure of 375 to 400 pounds.

*Copper arsenate is a definite chemical compound containing 40 percent copper and 40 percent arsenic pentoxide. In the course of manufacture the copper and arsenic pentoxide contents are reduced to 39 percent each.

Epidemiological conditions

Three pre-harvest sprays of liquid lime sulphur failed to control leaf spot in the Roach Orchards in 1937, and almost complete defoliation had occurred by the harvest period (July 22 - August 5). Selection of the trees for experimental purposes in 1938 was made in anticipation of the presence of abundant leaf spot inoculum. It was found, however, that most of the overwintering leaves were destroyed by early spring cultivation and sheet erosion of the soil. Consequently, the control of leaf spot did not become a serious problem in most of the experimental plats, although conditions were very favorable for severe attacks of leaf spot in the vicinity.

Mature ascospores of Coccomyces hiemalis Higgins were not found until May 18, although the period of full-bloom was exceptionally early (May 2-9). The first scattered leaf spot lesions appeared on the untreated control trees and in other Oceana County orchards on May 31. Examination of a limited number of apothecia on June 2 indicated that many ascospores were not discharged. The appearance of acervuli approximately 10 days after the rain of May 20 (Figure 2) strongly indicated that the first primary infections occurred on that date. Further observations showed that additional primary infections occurred during the rains of May 25 and 27.

The appearance of numerous lesions and resulting yellowing and defoliation on June 12 in neighboring orchards indicated that secondary infections began to occur with the rains of June 1 and 2.

An abnormal amount of rainfall throughout the latter part of May and the month of June, combined with comparatively warm temperatures (Figure 2), furnished ideal conditions for epidemic development of the disease in orchards inadequately protected. As observed in many of the orchards in Oceana County, successive defoliations occurred at approximately ten day intervals during rainy period throughout the remainder of the season.

Although the first infections of the season were noted on the untreated control trees, no defoliation due to leaf spot occurred until the time of harvest (July 22). Defoliation was complete on control trees the latter part of August. The fact that these untreated trees were lightly infected during the pre-harvest period indicates that this orchard had a much less acute leaf spot control problem than many orchards in the immediate vicinity.

Results

Although conditions for evaluating the fungicidal effectiveness of the spray materials were not optimum in the experimental orchards, excellent opportunities were afforded to determine the injuriousness of the spray treatments. As stated above, the trees were in a weakened condition due to defoliations of the previous seasons and it is generally recognized that trees with a lowered vitality are much more susceptible to spray injury than those that are vigorous and strongly growing.

No comparative determination of leaf spot infection was made during the season because there was very little infection on foliage sprayed with copper materials and very few lesions on foliage of the unsprayed control trees until late in the season.

The first yellowing and defoliation due to leaf spot in the experimental block occurred on two of the three unsprayed control trees on July 2. Severe leaf spot defoliation and yellowing in the plat sprayed with liquid lime sulphur did not occur until August 5-6, although the foliage showed many scattered lesions throughout the latter part of the pre-harvest period. Defoliation was complete the latter part of August.

Continuous observation throughout the season revealed that the amount of leaf spot on the trees sprayed with copper materials was not significant. Leaf spot infections caused only slight defoliation on unprotected new growth during the latter part of August and the period between the four-week spray and the after-harvest application. Such defoliations were particularly evident on the plats sprayed with Basicop-zinc sulphate-lime at 2-3/4-4-100 and 1½-½-½-100, as shown in Table 15.

Spray injury to the foliage was first noted June 5 on trees sprayed with liquid lime sulphur 2½-100. The injury was evidenced by a marked dwarfing and crinkling of the leaves. No further increase in the amount of injury in this plat was observed during the remainder of the season.

The first plats sprayed with copper materials to show foliage injury were the two sprayed with Basicop-lime 3-8-100 and Cupro K 3-100. The injury, as manifested by yellowing and losses of foliage, occurred June 9. Slight waves of yellowing and defoliation continued to occur at frequent intervals throughout the season on the plat sprayed with Cupro K 3-100. However, very little additional injury was observed on the plat sprayed with Basicop-lime 3-8-100. The cause of the first appearance of injury in these two plats was not determined. Evidence of injury in these plats first is at variance with the results of the 1937 experiments in which spray injury first appeared in plats sprayed with Basicop with or without small amounts of lime.

Severe yellowing of the foliage and resultant defoliation due to injury, occurred June 10 on plats sprayed with Basicop-borax 2-2-100 and 2-5-100. Defoliations, almost wholly caused by spray injury, continued to occur throughout the season until the loss of foliage was complete by the latter part of August.

Slight amounts of foliage injury became evident July 11 on plats sprayed with Basicop-lime at concentrations of 2-6-100, 2-4-100, and 2-2-100. Severe defoliation due to injury occurred in plats treated with Basicop 1½-100, Basicop-magnesium hydroxide 2-2-100 and 2-4-100, copper arsenate 3-100, copper arsenate-lime 3-3-100, and copper arsenate-lime 4-4-100.

Foliage of the plats sprayed with Basicop-iron sulphate-lime 2-2-2-100 and 2-2-4-100 was excellent in appearance until after cherry harvest. Although Anderson (1) and Stewart (91) stated that the addition of iron sulphate to cherry sprays decreased the "burning" of the leaves, severe defoliation due to spray injury occurred on both plats about August 6. However, very little additional injury occurred during the remainder of the season. Keitt, et al. (63) found that the efficiency of bordeaux mixture was not increased by the addition of iron sulphate.

The plats sprayed with Basicop-zinc sulphate-lime 2-¾-4-100, 2-1-1½-100, 1½-½-3-100, and 1½-½-½-100 showed no indication of spray injury throughout the entire season. Although a slight amount of leaf spot defoliation occurred in certain of these plats, as previously noted, they maintained the best appearance of the plats that were sprayed with proprietary copper compounds. Similar results have been obtained with Bordeaux 34 (basic copper sulphate) with zinc sulphate and lime by Kadow and Anderson (2, 57).

No significant foliage injury appeared in the plats sprayed with Basicop-lime 3-6-100. The use of either dolomitic or high-calcium limes at this concentration appeared to make little difference in the appearance of the plats.

The plat that received two sprays of bordeaux mixture 6-8-100 and two sprays of Basicop-lime 3-8-100 consistently maintained the best appearance of the plats in the experimental block. No defoliation due to leaf spot or spray injury occurred in the plat during the entire season.

Evidence of foliage injury in the plats sprayed with bordeaux mixture first appeared on July 29. The plats that received two pre-harvest sprays of bordeaux mixture 3-4-100, 4-5-100, and 6-8-100 had light amounts of yellowing and defoliation while plats receiving three pre-harvest sprays of corresponding concentrations had only a few scattered yellow leaves in the tree and very little defoliation. Further injury occurred on all plats during the last of August and the month of September, regardless of the pre-harvest spray schedule. Following the after-harvest applications on all plats sprayed with bordeaux, no difference could be noted in the amount of spray injury between plats receiving three or four sprays of each concentration. However, the largest amount of injury was noted in the plats sprayed with bordeaux mixture 6-8-100, while very little difference was evident between the amount of injury in the plats sprayed with bordeaux mixture 3-4-100 or 4-5-100.

The plat given two applications of lead arsenate 2-100 began to show very severe yellowing and defoliation due to spray injury on July 11. Losses of foliage continued to occur until defoliation was complete on August 8. Examination of the injured leaves showed the injury to be indistinguishable in appearance from that found in many of the plats sprayed with copper materials. This condition naturally suggests that some of the injury obtained in orchards sprayed commercially with copper compounds and which has hitherto been termed "copper injury" may have been caused, in part, by lead arsenate. Careful examination of the fruit and pedicels in this plat showed no indication of the injury which has been noted and described by Dutton (30) and Gloyer (46).

Final comparative evaluations of the spray treatments taken October 8 show, as presented in Table 13, that no foliage injury occurred in the experimental plats sprayed with Basicop-zinc sulphate-lime 2-¾-4-100, 2-1-1½-100, 1½-1-3-100, 1½-½-½-100, or in the plat sprayed with two applications of bordeaux mixture 6-8-100 and two sprays of Basicop-lime 3-8-100. Treatments of Basicop without lime at 1½-100, Basicop-magnesium hydroxide 2-2-100 or 2-4-100, Basicop-borax 2-2-100 or 2-5-100, Basicop-lime 2-2-100 or 2-4-100, copper arsenate 3-100, copper arsenate-lime 3-3-100 or 4-4-100, Cupro K 3-100, Fungiborde 4-100, and certain concentrations of bordeaux mixture were found to be unsatisfactory due to the moderate to heavy amounts of resulting spray injury to the foliage. Treatments causing only light amounts of spray injury, as Basicop-lime 2-6-100, 3-6-100, 3-8-100, and Basicop-magnesium lime 3-6-100 were satisfactory since the amount of injury was not considered commercially significant.

Although opportunities for determining the effectiveness of the materials against leaf spot were limited, observations again indicated the different concentrations of bordeaux mixture to be the most efficient of the fungicides tested. Under conditions of light leaf spot infection occurring in this experiment, no difference could be noted in the degree of disease control obtained with bordeaux mixture at concentrations of 6-8-100, 4-5-100, or 3-4-100. Also, the three-spray and four-spray programs of each concentration appeared to give equal control of leaf spot.

Treatments of Basicop-iron sulphate-lime at 2-2-2-100 and 2-2-4-100, Basicop-lime 2-2-100, 2-4-100, 2-6-100, 3-6-100, and 3-8-100, Basicop-magnesium lime 3-6-100, Basicop-zinc sulphate-lime 2-¾-4-100, 2-1-1½-100, and 1½-1-3-100, Cupro K 3-100, and Fungibordo 4-100 satisfactorily controlled leaf spot throughout the season.

Although much superior to liquid lime sulphur 2½-100, Basicop 1½-100, Basicop-magnesium hydroxide 2-2-100 and 2-4-100, and Basicop-zinc sulphate-lime 1½-½-½-100 did not adequately control leaf spot. The value of the use of four-spray programs of these materials at the given concentrations remains questionable, especially during seasons of abundant rainfall and in orchards with an abundance of leaf spot inoculum. It was also determined that two-pre-harvest sprays and one after-harvest application of Basicop-lime 3-6-100 were not sufficient to control the disease satisfactorily.

Very severe early foliage injury occurring in plats sprayed with Basicop-borax 2-2-100 and 2-5-100, copper arsenate 3-100, and copper arsenate-lime 3-3-100 and 4-4-100 concentrations prevented satisfactory evaluations of the combinations in regard to leaf spot control.

Relations of fungicides to the size of fruit

To determine the effect of the various sprays on the size of fruit, 50 cherries were similarily selected and picked from each quarter of the tops of all representative trees in each plat. Two hundred cherries were thus correspondingly chosen from each tree and the number carefully checked three times to prevent error. The weight of the cherries per tree was then determined to the nearest gram. The data on comparative fruit size determinations are presented in Table 14.

Reduction of fruit size caused by spray materials was not marked in 1938. Abnormal amounts of rainfall throughout the season tended to prevent dwarfing of the fruit.

The largest fruit in the experimental block was borne in plats sprayed with Basicop-magnesium hydroxide 2-2-100, Basicop-magnesium hydroxide 2-4-100, and lead arsenate 2-100. Following the observations of Keitt, et al. (63), the increased size of fruit in these plats may have been due, in part, to severe defoliations just prior to harvest. However, severe defoliations early in the summer appeared to have no special effect upon fruit size in plats sprayed with Copper arsenate-lime 3-3-100 and 4-4-100, Copper arsenate 3-100, and Basicop-borax at 2-2-100 and 2-5-100.

Combinations of Basicop-zinc sulphate-lime at 2-¾-4-100, 1½-½-½-100, 2-1-1½-100, or 1½-½-3-100 and Basicop-iron sulphate-lime at 2-2-2-100 or 2-2-4-100 showed no tendency to depress the fruit size.

No significant difference was found in the size of fruit from trees sprayed with Basicop-lime 2-2-100, Basicop-lime 2-4-100, liquid lime sulphur 2½-100, or Cupro K 3-100.

Trees given three sprays of Basicop-lime 3-6-100, in one instance, produced fruit slightly larger than cherries from trees receiving only two pre-harvest sprays of the same material and concentration. However, one plat in a different location in the orchard that also received three pre-harvest sprays of Basicop-lime 3-6-100, produced fruit much smaller than the plat which received two pre-harvest sprays.

Fruit of trees sprayed with Basicop 1½-100, Basicop-lime 3-8-100, Fungibordo 4-100, Basicop-lime 2-6-100, and Basicop-magnesium lime 3-6-100 was comparatively smaller than fruit of trees sprayed with liquid lime sulphur 2½-100.

Trees given three pre-harvest sprays of bordeaux mixture 3-4-100, 4-5-100, and 6-8-100 produced fruit smaller than trees given two pre-harvest sprays of corresponding concentrations. Fruit sprayed twice with bordeaux mixture 4-5-100 was 50 grams heavier per 100 cherries on an average than fruit receiving three pre-harvest applications of the same concentration. The difference in the size of fruit was less marked in plats given two-spray and three-spray programs of bordeaux mixture 6-8-100. No significant difference in fruit size occurred in plats receiving two and three sprays of bordeaux mixture 3-4-100 before harvest.

The size of cherries in the plats sprayed twice with bordeaux mixture 6-8-100 and once with Basicop 3-8-100 before harvest was the smallest in the experimental block. However, the fruit size was only slightly smaller than that of the plat given three pre-harvest sprays of bordeaux mixture 6-8-100 or of one plat that received three pre-harvest applications of Basicop-lime 3-6-100.

<u>Relation of early defoliation in 1937 to yield and size of fruit in 1938</u>

Plats sprayed with various sulphur materials in 1937 had severe early defoliations, while such defoliations were very slight in plats sprayed with copper compounds. All trees, regardless of spray treatment of the previous year received four pre-harvest sprays of Cupro K 3-100 in 1938.

To determine the effect of early defoliation in 1937 upon the total yield and size of fruit in 1938, all cherries picked from each tree were weighed to the nearest one-quarter of a pound and randomized selections of 100 cherries per tree were weighed to the nearest gram.

No data were taken upon the total yield of fruit per tree in 1937. Forty-nine trees that were defoliated early by leaf spot in 1937 produced an average of 49.7 pounds of fruit per tree the following year, as shown in Table 15. Forty-four trees, in which little early defoliation occurred the previous year, yielded an average of 55.9 pounds of cherries per tree. The figures presented do not truly represent the residual effect of leaf spot defoliation upon the subsequent yield of fruit as indicated by Dutton and Wells (33). Many of the trees that received sulphur sprays in 1937 were larger trees than those sprayed with copper materials and, consequently, bore more fruit. This condition naturally tended to obscure any effect of defoliation of the previous season toward reducing the total size of the crop. However, uneven ripening and exceptionally small fruit could be noted at the time of harvest by casual observation on trees that had poor control of the disease the previous year.

Determinations of the average weight in 1937 of 100 cherries from 30 copper sprayed trees showed the fruit to be slightly smaller than fruit from a corresponding number of trees sprayed with sulphur materials.

Comparative fruit size determinations in 1938 were based upon two plats, each including 30 trees used in the collection of similar data the previous year. (Table 15). One hundred cherries were correspondingly selected from each of 44 trees that had very poor control of the disease with sulphur sprays the previous year and from each of 49 trees that had good control of the disease with copper materials. Data presented in Table 15 show that cherries picked in 1938 from trees that had severe early defoliation due to leaf spot the previous season were considerably smaller than cherries from trees that had slight losses of foliage prior to harvest in 1937. Dutton and Wells (33) have also reported smaller fruit from trees defoliated by leaf spot the previous year.

Residual copper on foliage

The amount of copper residue on the foliage was determined for each plat at the end of the season. A disk, one centimeter square, was punched near the mid-rib from the center of each leaf. Ten disks were taken from four sides of each representative tree in a plat. Analyses were based upon the total number of disks from each plat.

As shown in Table 16, foliage sprayed with certain concentrations of bordeaux mixture, the bordeaux mixture and Basicop-lime combination, copper arsenate-lime, copper arsenate, and Basicop-iron sulphate-lime retained distinctly more copper than foliage receiving other treatments. Leaves receiving three sprays of bordeaux mixture retained less copper per unit area than leaves receiving four sprays of corresponding concentrations. Analyses showed that three sprays of bordeaux mixture 3-4-100 left almost as much copper deposit as four sprays of Basicop-magnesium lime 3-6-100.

Foliage sprayed with Basicop-lime 3-6-100, 3-8-100 and 2-4-100, or Basicop-borax 2-2-100 and 2-5-100 showed no appreciable difference in the amount of copper deposit, although not equal to the amount left on leaves receiving three sprays of bordeaux mixture 3-4-100.

Almost as much copper deposit was found on foliage sprayed with Basicop-zinc sulphate-lime 1½-½-3-100, 2-1-1½-100, 2-¾-4-100, 1½-½-½-100 and Basicop-lime 2-2-100 as on foliage sprayed with Basicop-lime 3-8-100. However, the data indicate that the weathering qualities of the Basicop-iron sulphate-lime treatments were superior to Basicop-zinc sulphate-lime sprays.

Foliage sprayed with Basicop-magnesium hydroxide 2-2-100 and 2-4-100, three applications of Basicop-lime 3-6-100, Basicop 1½-100, Basicop-lime 2-6-100, and Cupro K 3-100 retained less copper deposit than foliage receiving any of the other spray treatments.

<u>Observations on commercially sprayed orchards</u>

The Barden orchard, located at South Haven, Michigan, was treated with a four-spray program of Basicop-lime used at a concentration of 2½-5-100 which is slightly below the recommended concentration of 3-8-100 or 3-6-100. Very good control of the disease was obtained and no foliage injury was noted throughout the season.

The Booker orchard at Hart, Michigan received a three-spray program of Basicop-lime at 3-8-100. No injury resulting from the sprays was observed during the season. Control of leaf spot in this orchard was excellent until after the harvest period. No after-harvest aplication was made which accounts for the appearance of leaf spot that became evident the latter part of August.

The Jonassen orchard at Mears, Michigan, was heavily infected with cherry leaf spot during the early part of the season. The first leaf spot lesions were noted in this orchard on May 31. A severe wave of yellowing and defoliation of the leaves appeared on June 12 and was followed shortly by another on June 20. Unfortunate timing of sprays in relation to rains and an abnormal amount of rain resulted in a loss of protective action of the two sprays previously applied. Although another proprietary copper spray material had been used in the first two sprays, a change to Basicop-lime at 3-8-100 applied at 10 day intervals effectively checked the progress of the disease and gave no evidence of foliage injury. Bordeaux mixture 6-8-100 was used in the late after-harvest spray.

The Ellendale Farm orchard at Acme, Michigan, received a four-spray program of Basicop 3-8-100. The part of the orchard receiving sprays with proper timeliness showed no evidence of spray injury and had adequate control of leaf spot at the end of the season. In one section of the orchard a delay of approximately 20 days in the application of the third spray resulted in defoliation due to leaf spot. Immediately after the third spray was finally applied the progress of the disease was satisfactorily checked.

SUMMARY

Certain spray materials at selected concentrations were tested in Michigan in 1937 and 1938 to determine their relative fungicidal efficiency for the control of cherry leaf spot, Coccomyces hiemalis Higgins. Determinations of the injurious effects of the fungicides upon the foliage and fruit of cherry trees were also conducted.

The main portion of the experiment was conducted at Hart, Michigan, and supplementary studies were made at Empire, Omena, and Shelby, Michigan. The growing season of 1937 was especially favorable for the development of cherry leaf spot in Michigan. Although infections were well established in all plats, it became apparent early in the season that copper sprays were more effective in checking the disease than sulphur sprays. This condition was readily observed throughout the entire season. Unsprayed control trees and plats sprayed with dry lime sulphur 4-100 or 10-100, Electric sulphur 4-100, liquid lime sulphur 1-100 or 2½-100, and liquid lime sulphur with Electric sulphur 1-4-100 were completely defoliated due to leaf spot. Plats sprayed with Basicop 1½-100 and Basicop 1½-4-100 were the only plats sprayed with copper materials that showed a significant amount of defoliation caused by the disease. Basicop-lime 3-8-100 and 3-1-100, Basicop 3-100, Cupro K 3-100 and 6-100, and bordeaux mixture 3-4-100 and 6-8-100 satisfactorily controlled the disease throughout the season.

Evidence of spray injury to the foliage in 1937 was not noted in plats sprayed with the sulphur materials. Varying amounts of injury

occurred on trees sprayed with copper materials. It was readily determined that the use of Basicop without lime was unsatisfactory (i.e. Basicop 1½-100 and 3-100) due to severe foliage injury, and that the addition of lime decreased the amount of defoliation. No appreciable amount of spray injury occurred in the plat sprayed with Basicop-lime 3-8-100, while Basicop 3-100 with only one pound of lime caused severe injury. Cupro K at concentrations of 3-100 or 6-100 also caused considerable spray injury to the foliage. Losses of leaves occurred late in the season in the plats sprayed with bordeaux mixture 3-4-100 and 6-8-100.

In 1937 the data on early leaf spot infections in the plats sprayed with sulphur and the unsprayed control trees were found to correspond to the amount of defoliation at the end of the season. However, the amount of early infection in the plats sprayed with copper material was found to indicate in no way the amount of resultant defoliation late in the season, thus showing that the copper materials may impede the progress of the disease after it has once become well established, as has been previously reported by Cation (20).

Plats which received three sprays of Basicop-lime 3-8-100, bordeaux mixture 3-4-100 and 6-8-100 in 1937 had more defoliation than when given four sprays, while plats receiving three applications of Cupro K 3-100 and 6-100 resulted in less defoliation than four sprays.

The data in one instance of the experiment in 1937 show that the ascosporic inoculum immediately beneath each tree was the determining factor in the resulting amount of infection, while the amount of lateral dissemination of inoculum which may have occurred was insignificant.

The application of a pre-bloom spray of liquid lime sulphur was shown to be of definite value in the control of the disease in 1937. However, observations indicated that the effectiveness of pre-bloom applications of liquid lime sulphur in seasons of abundant rainfall is lost during the late summer, early fall, and in the six-week period prior to the application of the after-harvest spray.

It was determined in 1937 that plats losing considerable foliage just prior to harvest bore the largest cherries. This condition was especially marked in plats in which exceedingly poor control was obtained with the use of sulphur sprays. Definite dwarfing of the fruit occurred on trees sprayed with bordeaux mixture 6-8-100. Reduction of the size of fruit was not as pronounced on trees sprayed with bordeaux mixture 3-4-100. Cherries from trees sprayed with Basicop 1½-100 and 3-100, Basicop-lime 3-1-100, 3-8-100, and 1½-4-100, and Cupro K 3-100 and 6-100 compared favorably in size to fruit from trees sprayed with liquid lime sulphur 2½-100 and were superior in size to cherries from plats sprayed with either bordeaux mixture 3-4-100 or 6-8-100. No dwarfing of the fruit from trees given two pre-harvest sprays of bordeaux mixture 6-8-100 at Empire, Michigan, was noted.

Plats that received four sprays of copper materials in 1937 retained a greater amount of residual copper in each instance than plats given three sprays of the same material and concentration. The data show that bordeaux mixture 6-8-100 or 3-4-100 used either in a four-spray or three-spray program had superior adhesive qualities to most of the concentrations of Basicop or Basicop and lime. The data also show that Cupro K had adhesive qualities superior to Basicop when the two materials were applied at equal copper content concentrations. The addition of lime to Basicop did not significantly affect the weather resisting qualities of the fungicide in 1937.

Experiments in 1938 were conducted at Hart, Michigan. The leaf spot disease was not as severe in the experimental blocks as in the immediate vicinity as indicated by the unsprayed control trees. As in 1937, liquid lime sulphur did not adequately control the disease. Bordeaux mixture 3-4-100, 4-5-100, and 6-8-100 completely controlled the disease whether three or four sprays were applied. The minimum concentration of Basicop necessary to control leaf spot satisfactorily appeared to be 2 pounds in 100 gallons of spray. Plats sprayed with Basicop-iron sulphate-lime 2-2-2-100 and 2-2-4-100, Basicop-lime 2-2-100, 2-4-100, 2-6-100, 3-6-100, and 3-8-100, Basicop-magnesium lime 3-6-100, Basicop-zinc sulphate-lime 1½-1-3-100, 2-¾-4-100 and 2-1-1½-100, Cupro K 3-100, and Fungibordo 4-100 had adequate control of the disease throughout the season. Basicop 1½-100, Basicop-zinc sulphate-lime 1½-½-½-100 did not satisfactorily control leaf spot.

Conditions were favorable for evaluating the comparative injuriousness of spray treatments in 1938. Foliage injury was so severe in plats sprayed with Basicop-borax 2-2-100 and 2-5-100, copper arsenate 3-100, and copper arsenate-lime 3-3-100 and 4-4-100 that satisfactory evaluations of the materials in regard to disease control were prevented. Small amounts of lime in addition to zinc sulphate completely checked foliage injury when used with Basicop. No spray injury occurred in plats treated with Basicop-zinc sulphate-lime 1½-½-½-100, 1½-1-3-100, 2-¾-4-100, 2-1-1½-100, or in the plat sprayed with two applications of bordeaux mixture 6-8-100 and two sprays of Basicop-lime 3-8-100. Basicop 1½-100, Basicop-lime 2-2-100 and 2-4-100, Basicop-iron sulphate-lime

2-2-2-100 and 2-2-4-100, Basicop-magnesium hydroxide 2-2-100 and 2-4-100, Cupro K 3-100, Fungibordo 4-100 and certain concentrations of bordeaux mixture caused moderate to heavy amounts of foliage injury. Sprays of Basicop-lime 2-6-100, 3-6-100, 3-8-100, and Basicop-magnesium lime 3-6-100 caused only insignificant amounts of foliage injury. Spray injury caused complete defoliation in the plat given two pre-harvest sprays of lead arsenate 2-100.

Spray materials did not cause marked dwarfing of the fruit in 1938 since abnormal amounts of rainfall throughout the season tended to prevent reduction of fruit size.

The residual effect of cherry leaf spot defoliation upon the size of fruit was determined. In 1938 trees that had severe early defoliation the previous season produced conspicuously smaller, unevenly ripened fruit than trees that had little loss of foliage in 1937 prior to the harvest period.

Analyses of the residual copper on cherry foliage at the end of the season again showed that bordeaux mixture has weather resisting qualities superior to Basicop or Basicop with lime. Foliage that received four sprays of copper materials retained more copper per unit area than leaves that were given three sprays of the material at the same concentration. The addition of iron sulphate to Basicop and lime increased the adhesiveness of copper material. Borax, magnesium hydroxide, or zinc sulphate applied in combination with Basicop or Basicop and lime did not appear to affect significantly the amount of copper residue on the foliage at the end of the season. Copper arsenate or copper arsenate with lime retained more copper per unit area than the different Basicop combinations.

CONCLUSIONS

1. Copper sprays are more effective in controlling the disease than sulphur sprays.
2. Copper materials are more efficient than sulphur materials in checking the progress of the disease after infection has once become well established.
3. A four-spray program of Basicop-lime 3-8-100 gives a good control of cherry leaf spot in years of normal rainfall and causes little appreciable spray injury. Basicop-lime 3-6-100 appears to give equally satisfactory results.
4. Two pounds of Basicop in 100 gallons of spray appears to be the minimum concentration necessary to control the disease satisfactorily.
5. Basicop-zinc sulphate-lime 2-1-1½-100 appears to be a promising spray combination.
6. Cupro K without lime controls the disease satisfactorily but causes serious foliage injury.
7. Bordeaux mixture gives excellent control of the disease but frequently causes severe spray injury.
8. Pre-bloom applications of liquid lime sulphur 2½-100 may be of definite value in certain years for the control of cherry leaf spot.
9. Four sprays of dry lime sulphur 4-100 or 10-100, Electric sulphur 4-100, liquid lime sulphur 1-100 or 2½-100, or liquid lime sulphur with Electric sulphur 4-100 fail to control the disease

in certain years.

10. The amount of ascosporic inoculum immediately beneath each tree may be the determining factor in the resultant amount of early infections. In certain years the amount of lateral dissemination of primary inoculum is not significant.

11. Basicop used without sufficient lime causes severe foliage injury.

12. Basicop applied in combination with borax or magnesium hydroxide increases the amount of foliage injury.

13. Copper arsenate or copper arsenate and lime may cause severe foliage injury.

14. Lead arsenate 2-100 is capable of causing severe foliage injury when used alone.

15. Three pre-harvest sprays of bordeaux mixture cause definite dwarfing of the fruit in certain years.

16. Basicop, Basicop-lime, and Basicop-zinc sulphate-lime cause no appreciable dwarfing of the fruit when compared to fruit sprayed with liquid lime sulphur 2½-100.

17. Trees that lose considerable foliage just prior to harvest may bear the largest fruit.

18. Bordeaux mixture has adhesive qualities superior to Basicop, Basicop-lime, Basicop-iron sulphate-lime, or Basicop-zinc sulphate-lime.

19. The addition of iron sulphate to Basicop and lime increases the adhesiveness of the copper material but may cause serious foliage injury.

20. Early severe defoliation may cause the production of small unevenly ripened fruit the following year.

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TABLES

Table 1

Concentrations of materials used to make 100 gallons of spray in experiment at Roach Orchard, Hart, Michigan, 1937.

Material	Concentration in pounds
Basicop	3-100
Basicop	1½-100
Basicop-lime	3-8-100
Basicop-lime	3-1-100
Basicop-lime	1½-4-100
Bordeaux mixture	6-8-100
Bordeaux mixture	3-4-100
Cupro K*	6-100
Cupro K	3-100
Dry lime sulphur	10-100
Dry lime sulphur - 325-mesh sulphur	2-4-100
Dry lime sulphur	4-100
Electric sulphur**	4-100
Liquid lime sulphur	1-100
Liquid lime sulphur - Electric sulphur	1-4-100
Liquid lime sulphur	2½-100

*Copper oxychloride principal ingredient, manufactured by Rhom & Hass Co.

**A wettable sulphur manufactured by Stauffer Chemical Company.

Table 2

Comparative percentages of infected leaves at
Roach Orchard, Hart, Michigan June 23, 1937.*

Treatment	Leaves Infected	Leaves Non-Infected	Total Leaves Counted*	Amount of Infection
	number	number	number	per cent
Basicop-lime 3-8-100	61	204	265	29.9
Bordeaux 6-8-100	105	275	385	38.1
Basicop-lime 3-1-100	114	255	369	44.7
Cupro K 6-100	99	219	318	45.2
Bordeaux 3-4-100	103	227	330	45.3
Basicop-lime 1½-4-100	128	251	379	50.9
Basicop 3-100	157	298	455	52.6
Cupro K 3-100	154	271	425	56.8
Dry lime-sulphur 2 lbs., 325-mesh sulphur 4 lbs. - 100	132	232	364	56.8
Liquid lime-sulphur 2½-100	145	249	394	60.9
Dry lime-sulphur 10-100	134	220	354	60.9
Basicop 1½-100	195	304	499	64.1
Liquid lime-sulphur 1-100	147	199	346	73.8
Dry lime-sulphur 4-100	168	222	390	75.6
Electric sulphur 4-100	156	200	356	78.0
Liquid lime-sulphur and Electric sulphur (1-4-100	163	207	370	78.7
Check tree	---	---	---	98.0

*This table has been previously published in the Michigan Agricultural Experiment Station Quarterly Bulletin (22).

**Counts were made on four representative trees in each plat.

Table 3

Comparative evaluations of plat treatments at
Roach Orchard, Hart, Michigan, June 30 - July 1, 1937.

Material and Concentration	Defoliation Leaf spot	Defoliation Spray injury	Foliage Appearance
Basicop-lime 3-8-100	0	0	Excellent
Basicop-lime 3-1-100	Trace	Trace	Good
Basicop-lime 1½-4-100	1	0	Good
Basicop 3-100	0	1	Good
Basicop 1½-100	0	Trace	Good
Cupro K 6-100	0	Trace	Good
Cupro K 3-100	Trace	Trace	Good
Bordeaux mixture 6-8-100	0	0	Excellent
Bordeaux mixture 3-4-100	0	0	Excellent
Dry lime sulphur 325 mesh sulphur 2-4-100	3	0	Poor
Dry lime sulphur 4-100	3	0	Poor
Dry lime sulphur 10-100	1-2	0	Poor
Electric sulphur 4-100	3	0	Poor
Liquid lime sulphur 1-100	2	0	Poor
Liquid lime sulphur Electric sulphur 1-4-100	3	0	Poor
Liquid lime sulphur 2½-100	1-2	0	Poor
Control trees	3	0	Poor

Legend for Table 3:

0 - No defoliation
Trace - Very slight defoliation
1 - Slight defoliation
2 - Moderate defoliation
3 - Heavy defoliation

Table 4

Comparative defoliation in experimental plats at Roach Orchard, Hart, Michigan, September 25, 1937.*

Treatment	Leaves Missing	Leaves Present	Total Leaves Counted	Representative Trees Sampled	Amount of Defoliation
	number	number	number	number	per cent
Basicop-lime 3-8-100	110	1,662	1,772	5	6.2
Bordeaus 3-4-100	245	1,981	2,226	5	11.0
Bordeaux 6-8-100	293	1,684	1,977	5	14.8
Basicop-lime 3-8-100**	369	1,742	2,111	6	17.4
Bordeaux 3-4-100**	332	1,486	1,818	6	18.2
Cupro K 3-100**	325	1,146	1,471	4	22.0
Bordeaux 6-8-100**	481	1,676	2,157	6	22.2
Cupro K 6-100**	192	620	812	3	23.6
Basicop 3-100	1,169	3,393	4,562	12	25.6
Cupro K 3-100	534	1,301	1,835	5	29.1
Basicop-lime 3-1-100	1,110	2,427	3,537	10	31.3
Cupro K 6-100	407	879	1,286	3	31.6
Basicop 1½-100	1,255	2,523	3,778	9	33.2
Basicop-lime 1½-4-100	1,433	2,448	3,881	12	36.9
Dry lime-sulphur 10-100	1,889	921	2,810	8	67.2
Liquid lime sulphur 2½-100	2,816	801	3,617	9	77.8
Unsprayed control	370	6	376	1	98.4

*See footnote (*) at bottom of page 86.

**Received no after-harvest application.

Table 5

Effectiveness of pre-bloom sprays of liquid lime sulphur at Roach Orchard, Hart, Michigan, 1937

Plat No.	Spray Treatment in 1936 Material	Leaf Spot Control obtained in 1936	Ascosporic Inoculum 1937	Pre-bloom Spray 1937	Petal-fall Spray 1937	Two-week Spray 1937	Infection June 23 1937 Per cent	Defoliation Sept. 25 1937 Per cent
1	Copper	Excellent	Scarce	May 18	May 28	June 11	---	33.6
2	Copper	Excellent	Scarce	---	May 28	June 11	---	47.4
16	Lime sulphur	Poor	Abundant	May 18	May 28	June 11	2.65	60.7
17	Lime sulphur	Poor	Abundant	---	May 28	June 11	61.0	69.3
42	Lime sulphur	Poor	Abundant	---	May 30	June 16	58.0	79.0

Table 6

Comparative fruit size determinations at
Roach Orchard, Hart, Michigan, July 26, 1937.*

Treatment	Total Weight of 600 Cherries**	Average Weight of 600 Cherries
	grams	grams
Liquid lime-sulphur (1 gal.) and 4 lbs. Electric sulphur - 100	2,291	381.8
Liquid lime-sulphur 1 gal. - 100	2,289	381.5
Basicop 3-100	2,286	381.0
Cupro K 3-100	2,285	380.8
Electric sulphur 4 lbs. - 100	2,283	380.5
Liquid lime-sulphur 2½-100	2,219	369.5
Basicop 1½-100	2,199	366.5
Basicop-lime 3-8-100	2,177	362.8
Basicop-lime 3-1-100	2,165	360.8
Cupro K 6-100	2,127	354.5
Dry lime-sulphur (2 lbs.) and 325-mesh sulphur (4 lbs.) - 100	2,083	347.1
Basicop-lime- 1½-4-100	2,071	345.1
Bordeaux 3-4-100	2,031	338.5
Dry lime-sulphur 10 lbs. - 100	2,017	336.1
Bordeaux 6-8-100	1,747	291.1

*See footnote (*) at bottom of page 86.

**100 cherries were picked from each of six representative trees in a plat.

Table 7

Analysis of residual copper deposit on leaf samples collected October 9, 1937, at Roach Orchard, Hart, Michigan.*

Treatment	Amount of Copper per 100 Disks	Amount of Copper by Weight
	grams	per cent
Bordeaux 6-8-100	.00255	.231
Cupro K 6-100	.00099	.117
Bordeaux 6-8-100 ***	.00107	.109
Bordeaux 3-4-100	.00080	.092
Cupro K 6-100 ***	.00052	.063
Basicop 3-100	.00050	.062
Bordeaux 3-4-100 ***	.00054	.054
Basicop-lime 3-8-100	.00050**	.050
Cupro K 3-100	.00054	.048
Basicop-lime 3-8-100 ***	.00042	.043
Basicop-lime 1½-4-100	.00035**	.036
Cupro K 3-100 ***	.00034	.034
Basicop 1½-100	.00026	.025
Control tree ****	.00027	.018
Basicop-lime 3-1-100	No record	

*See footnote (*) at bottom of page 86.
**These disks were not counted but the average weight of 100 disks in the remaining samples was used to figure the number of disks.
***Received but three pre-harvest sprays.
****Received one after-harvest spray of Basicop-lime 2-2-100.

Table 8

Comparative fruit size determinations at
Field Orchard, Shelby, Michigan, July 21, 1937.*

Treatment	Trees Sampled	Cherries Picked	Total Weight	Average Weight of 100 Cherries
	number	number	grams	grams
Basicop-lime 3-8-100	14	1,367	6,379.4	462.2
Cupro K 6-100	15	1,500	6,837.0	459.3
Liquid lime-sulphur 2½-100	12	1,191	5,465.2	455.8

*See footnote (*) at bottom of page 86.

Table 9

Comparative spray injury determinations at the McClary Orchard, Empire, Michigan, August 8, 1937*

Treatment	Spurs Counted	Spurs Showing Yellow Leaves	Spurs Showing Yellow Leaves
	number	number	per cent
Basicop-lime 2-1-100	200	6	3.0
Cupro K 4-100	460	123	26.0
Bordeaux 4-5-100	619	82	13.0

*See footnote (*) at bottom of page 86.

Table 10

Comparative fruit size determinations at
the McClary Orchard, Empire, Michigan, July 30, 1937*

Treatment	Applications	Cherries Weighed	Total Weight	Average weight of 100 Cherries
	number	number	grams	grams
Bordeaux 4-5-100	2	2,400	9,475.0	394.7
Basicop-lime 2-1-100	3	2,400	9,376.0	390.6
Cupro K 4-100	3	2,400	8,644.0	360.0
Control (unsprayed)	0	600	2,714.0	452.3

*See footnote (*) at bottom of page 86.

Table 11

Comparative fruit size determinations at the Thomas Smith Orchard, Omena, Michigan, July 31, 1937*

Treatment	Representative Trees Sampled	Cherries Picked	Total Weight	Average Weight of 100 Cherries
	number	number	grams	grams
Lime-sulphur 2½-100	20	2,000	6,782	339.1
Basicop-lime 1½-1-100	18	2,000	6,213	310.6
Cupro K 3-100	20	2,000	6,199	309.9

*See footnote (*) at bottom of page 86.

Table 12

Spray dates and concentrations of materials used to make 100 gallons of spray in experiment at Roach Orchard, Hart, Michigan, 1938

Material	Concentration	Spray Applications			
		Petal-Fall	Two-Week	Four-Week	After-Harvest
		Date	Date	Date	Date
Basicop	1½-100	May 10	May 28	June 16	August 6
Basicop-borax	2-2-100	10	30	16	7
Basicop-borax	2-5-100	10	30	16	7
Basicop-iron sulphate-lime	2-2-2-100	10	30	16	6
Basicop-iron sulphate-lime	2-2-4-100	10	30	16	6
Basicop-lime	3-8-100	10	27	16	6
Basicop-lime	3-6-100	10	27	16	6
Basicop-lime	3-6-100	10	27		6
Basicop-lime (magnesium	3-6-100	22	June 6	20	7
Basicop-lime	2-6-100	10	May 27	16	6
Basicop-lime	2-4-100	10	28	16	6
Basicop-lime	2-2-100	10	28	16	6
Basicop-magnesium hydroxide	2-2-100	10	30	16	7
Basicop-magnesium hydroxide	2-4-100	10	30	16	7
Basicop-zinc sulphate-lime	2-3/4-4-100	10	28	16	6
Basicop-zinc sulphate-lime	2-1-1½-100	10	28	16	6
Basicop-zinc sulphate-lime	1½-½-3-100	10	30	16	7

Table 12 (continued)

Material	Concentration	Spray Applications: Petal-Fall Date	Two-Week Date	Four-Week Date	After-Harvest Date
Basicop-zinc sulphate-lime	1½-½-½-100	May 10	May 30	June 16	August 7
Bordeaux mixture	6-8-100	10	30	16	6
Bordeaux mixture	6-8-100	10	30		6
Bordeaux mixture	4-5-100	10	30	16	6
Bordeaux mixture	4-5-100	10	30		6
Bordeaux mixture	3-4-100	10	30	16	6
Bordeaux mixture	3-4-100	10	30		6
Bordeaux mixture and Basicop-lime	6-8-100 (two sprays) 3-8-100 (two sprays)	22	June 6	30	7
Copper arsenate	3-100	22	6	20	7
Copper arsenate-lime	3-3-100	22	6	20	7
Copper arsenate-lime	4-4-100	22	6	20	7
Cupro K	3-100	10	May 28	16	6
Fungiborde	4-100	22	June 6	20	6
Lead arsenate	2-100		6	20	
Liquid lime sulphur	2½-100	10	May 28	16	6

Table 13

Comparative Evaluations of Spray Treatments in Experimental Block, Roach Orchard, Hart, Michigan, October 8, 1938.

Plat Treatment		Control	Injury
Basicop	1½-100	Fair	Very heavy
Basicop-borax	2-2-100	---*	Very heavy
Basicop-borax	2-5-100	---*	Very heavy
Basicop-iron sulphate-lime	2-2-2-100	Good	Moderate
Basicop-iron sulphate-lime	2-2-4-100	Good	Moderate
Basicop-lime	2-2-100	Good	Moderate
Basicop-lime	2-4-100	Good	Moderate
Basicop-lime	2-6-100	Good	Light
Basicop-lime (Three sprays)	3-6-100	Fair	Light
Basicop-lime	3-6-100	Good	Light
Basicop-magnesium lime	3-6-100	Good	Light
Basicop-lime	3-8-100	Good	Light
Basicop-magnesium hydroxide	2-2-100	Fair	Very heavy
Basicop-magnesium hydroxide	2-4-100	Fair	Very heavy
Basicop-zinc sulphate-lime	2-¾-4-100	Good	None
Basicop-zinc sulphate-lime	2-1-1½-100	Good	None
Basicop-zinc sulphate-lime	1½-½-3-100	Good	None
Basicop-zinc sulphate-lime	1½-½-½-100	Fair	None
Bordeaux mixture (Three sprays)	6-8-100	Excellent	Very heavy
Bordeaux mixture	6-8-100	Excellent	Heavy
Bordeaux mixture (Three sprays)	4-5-100	Excellent	Heavy
Bordeaux mixture	4-5-100	Excellent	Moderate
Bordeaux mixture (Three sprays)	3-4-100	Excellent	Heavy

Table 13 (continued)

Plat Treatment		Control	Injury
Bordeaux mixture	3-4-100	Excellent	Moderate
Bordeaux mixture (two sprays and Basicop-lime (two sprays)	6-8-100 3-8-100	Excellent	None
Copper arsenate	3-100	---*	Very heavy
Copper arsenate-lime	3-3-100	---*	Very heavy
Copper arsenate-lime	4-4-100	---*	Very heavy
Cupro K	3-100	Good	Very heavy
Fungibordo	4-100	Good	Moderate
Lead arsenate (Two sprays)	2-100	---*	Very heavy
Liquid lime sulphur	2½-100	Poor	Light

*Early severe foliage injury prevented satisfactory evaluation of the material in regard to leaf spot control.

Table 14

Comparative fruit size determinations at
Roach Orchard, Hart, Michigan July 21-23, 1938

Treatment*		Representative trees Sampled **	Total Weight of Cherries Sampled	Average Weight of 100 Cherries
		number	grams	grams
Basicop-magnesium hydroxide	2-2-100	5	4273	427.3
Basicop-magnesium hydroxide	2-4-100	6	49995	416.2
Lead Arsenate (Two sprays)	2-100	7	5768	412.0
Basicop-zinc sulphate-lime	2-¾-4-100	10	8232	411.6
Basicop-lime	2-4-100	10	8042	402.1
Basicop-zinc sulphate-lime	1½-½-½-100	6	4816	401.3
Basicop-lime	2-2-100	3	2404	400.6
Liquid lime sulphur	2½-100	7	5562	397.2
Basicop-iron sulphate-lime	2-2-2-100	5	3966	396.6
Basicop-zinc sulphate-lime	2-1-1½-100	9	7073	392.9
Bordeaux mixture (Two sprays)	4-5-100	6	4701	391.7
Cupro K	3-100	10	7815	390.7
Copper arsenate-lime	3-3-100	6	4682	390.1
Basicop-zinc sulphate-lime	1½-½-3-100	9	6997	388.7
Basicop-lime	3-6-100	5	3849	384.9
Copper arsenate	3-100	6	4618	384.8
Basicop-lime (Two sprays)	3-6-100	5	3810	381.0
Basicop-borax	2-2-100	6	4491	374.2
Basicop-borax	2-5-100	6	4460	371.6
Basicop	1½-100	6	4420	368.3

Table 14 (continued)

Treatment*		Representative trees Sampled**	Total Weight of Cherries Sampled	Average Weight of 100 Cherries
		number	grams	grams
Basicop-lime	3-8-100	10	7275	363.7
Basicop-iron sulphate-lime	2-2-4-100	3	2171	361.8
Fungibordo	4-100	12	8635	359.7
Basicop-lime	2-6-100	10	7148	357.4
Copper arsenate-lime	4-4-100	5	3561	356.1
Bordeaux mixture (Two sprays]	6-8-100	12	8412	350.5
Bordeaux mixture (Two sprays)	3-4-100	8	5563	347.6
Bordeaux mixture	3-4-100	9	6161	342.2
Basicop-magnesium lime	3-6-100	4	2728	341.0
Bordeaux mixture	4-5-100	5	3410	341.0
Bordeaux mixture	6-8-100	10	6688	334.4
Basicop-lime	3-6-100	4	2670	333.7
Bordeaux mixture (two sprays and Basicop-lime (one spray)	6-8-100 3-8-100	7	4628	330.5

*Each treatment consisted of three pre-harvest sprays unless otherwise indicated.

**Two hundred cherries were picked from each representative tree in a plat.

Table 15

Relation of early defoliation in 1937 to
total yield and size of fruit in 1938

1937				1938					
Treatment	Early Defoliation	Total* Weight of 3000 Cherries grams	Average Weight of 100 Cherries grams	Treatment	Number of Trees	Total Yield pounds	Average Yield per tree pounds	Total** Weight of Cherries Sampled grams	Average Weight of 100 Cherries grams
Copper	Slight	1774.6	354.9	Copper	49	2,437.2	49.7	22,790.0	385.5
Sulphur	Very severe	1849.4	369.8	Copper	44	2,459.7	55.9	17,444.0	396.4

*100 cherries were selected from 30 representative trees.

**100 cherries were selected from each tree.

Table 16

Analysis of residual copper deposit on leaf samples collected at Roach Orchard, Hart, Michigan, October 3, 1938.

Treatment*		Representative trees sampled**	Amount of copper in whole sample	Average Amount of Copper per square centimeter of leaf area
		number	milligrams	milligrams
Bordeaux mixture	6-8-100	10	1.94	.0194
Bordeaux mixture	4-5-100	6	.630	.0105
Bordeaux mixture (three sprays)	6-8-100	11	1.15	.01045
Bordeaux mixture (three sprays)	4-5-100	5	.518	.01036
Bordeaux mixture*** (two sprays) and	6-8-100			
Basicop-lime (two sprays)	3-8-100	8	.795	.00993
Copper arsenate-lime***	4-4-100	6	.555	.00925
Copper arsenate-lime	4-4-100	6	.479	.00798
Copper arsenate***	3-100	6	.444	.0074
Copper arsenate-lime***	3-3-100	6	.358	.00596
Bordeaux mixture	3-4-100	9	.535	.00594
Basicop-iron sulphate-lime	2-2-4-100	7	.368	.00525
Basicop-iron sulphate-lime	2-2-2-100	5	.260	.0052
Fungibordo	4-100	12	.463	.00385
Basicop-magnesium lime	3-6-100	4	.127	.00317
Bordeaux mixture (three sprays)	3-4-100	9	.280	.00311

Table 16 (continued)

Treatment*		Representative trees sampled**	Amount of copper in whole sample	Average Amount of Copper per square centimeter of leaf area
			milligrams	milligrams
Basicop-lime	3-6-100	6	.163	.00271
Basicop-lime	3-6-100	4	.108	.0027
Basicop-lime	2-4-100	11	.270	.00245
Basicop-borax***	2-2-100	6****	.038	.00223
Basicop-borax***	2-5-100	6	.133	.00221
Basicop-lime	3-8-100	11	.225	.00204
Basicop-zinc sulphate-lime	1½-½-3-100	8	.163	.00203
Basicop-zinc sulphate-lime	2-1-1½-100	8	.155	.00193
Basicop-zinc sulphate-lime	2-¾-4-100	10	.188	.00188
Basicop-zinc sulphate-lime	1½-½-½-100	6	.109	.00181
Basicop-lime	2-2-100	6	.105	.00175
Basicop-magnesium hydroxide ***	2-2-100	6	.090	.00150
Basicop-magnesium hydroxide ***	2-4-100	6	.090	.00150
Basicop-lime (three sprays)	3-6-100	6	.089	.00148
Basicop	1½-100	6	.089	.00148
Basicop-lime	2-6-100	10	.143	.00143
Cupro K	3-100	10	.114	.00114

*Unless otherwise indicated, each treatment consisted of four sprays.
**Ten disks collected from each representative tree.
***Samples collected on October 8, 1938.
****Only 17 disks were used in copper determinations.

FIGURES

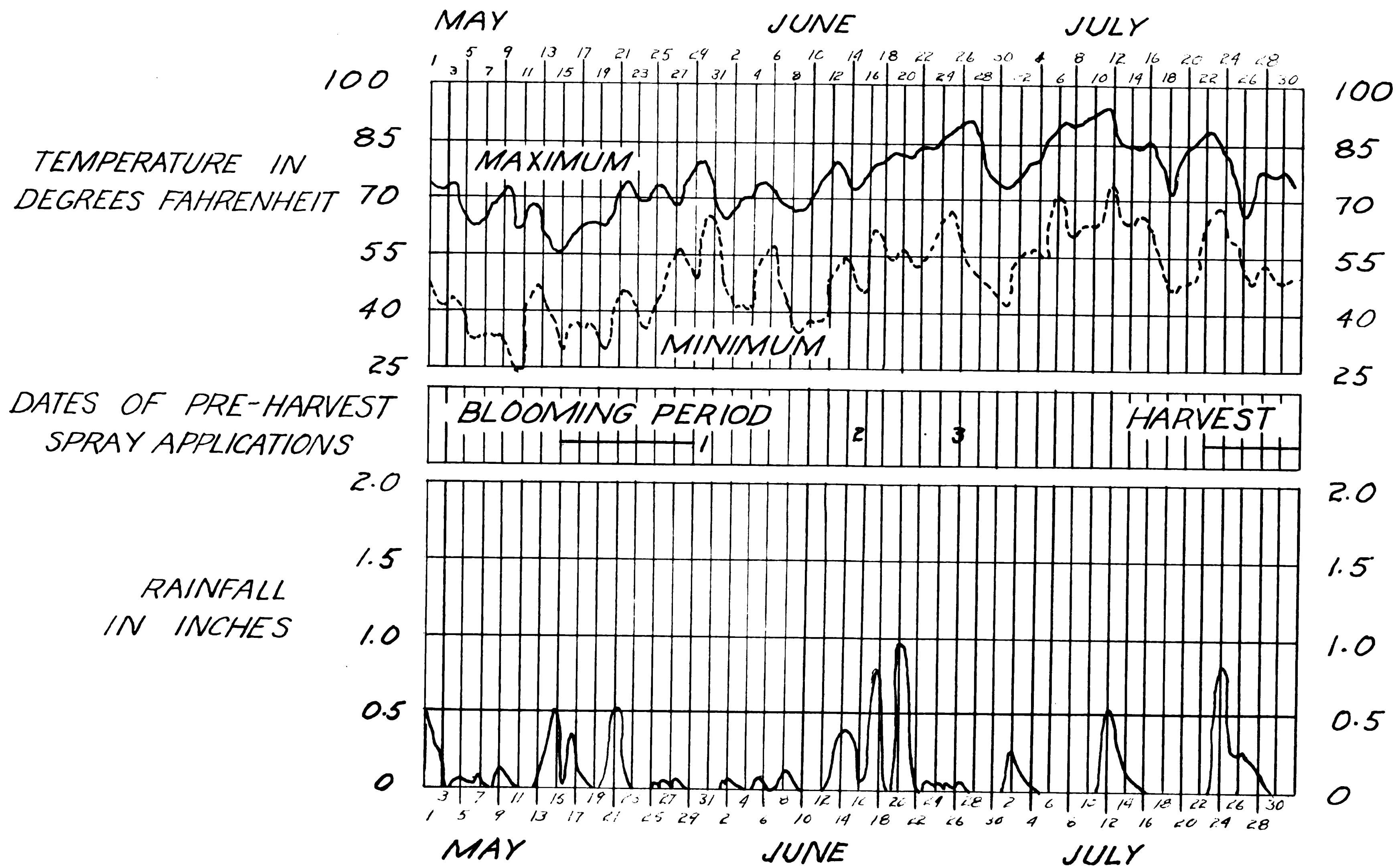

FIGURE I TEMPERATURE-RAINFALL CHART AND PRE-HARVEST SPRAY SCHEDULE AT ROACH ORCHARD, HART, MICHIGAN 1937

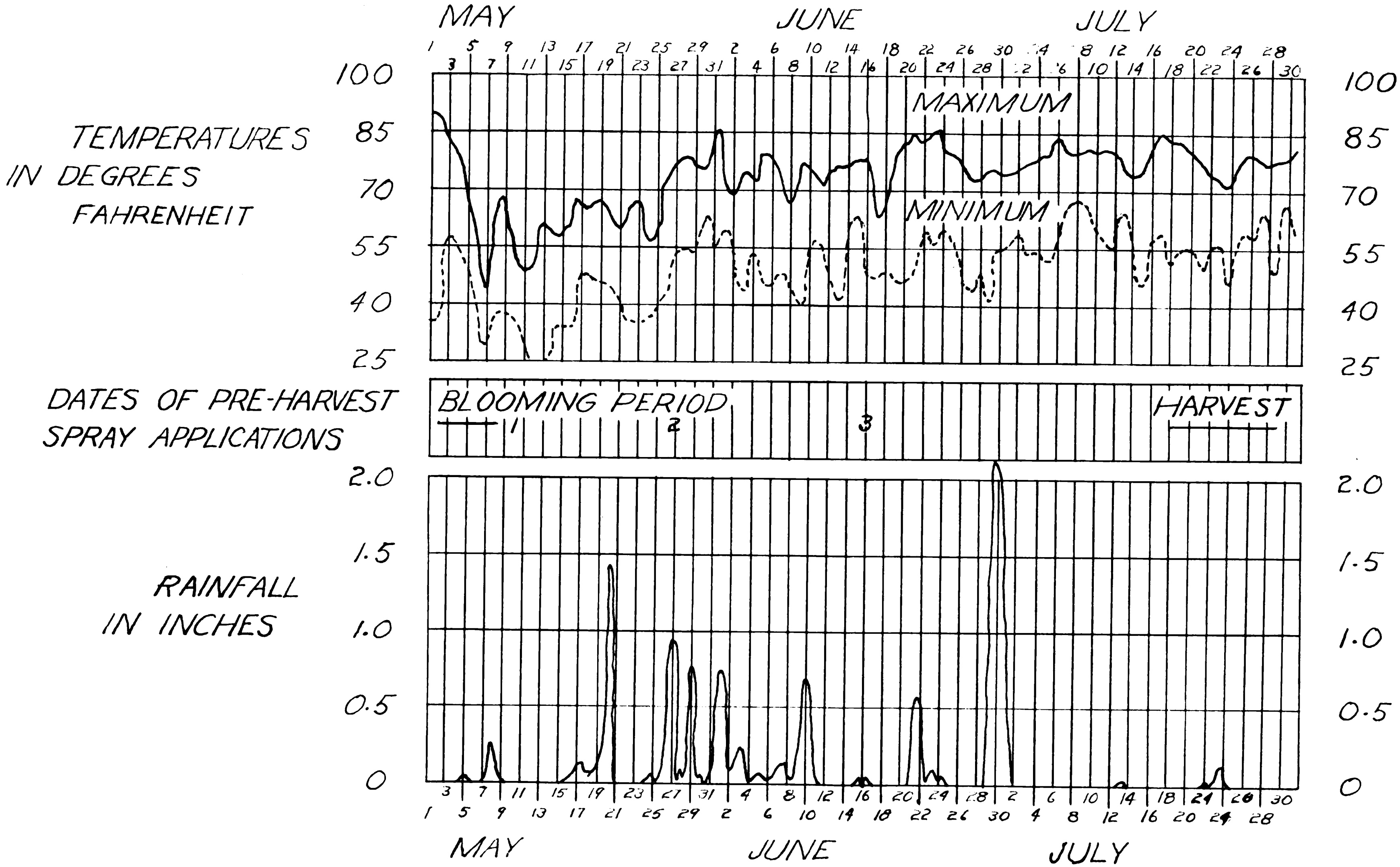

FIGURE II TEMPERATURE-RAINFALL CHART AND PRE-HARVEST SPRAY SCHEDULE AT ROACH ORCHARD, HART, MICHIGAN, 1938.