THE INFLUENCE OF CERTAIN SPRAY MATERIALS ON THE SIZE OF FRUIT IN THE SOUR CHERRY

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Introduction

Perhaps the most striking difference between orcharding of the present and that of a generation ago lies in the control of insect and fungous pests which has developed in this period. Men still actively engaged in fruit growing were growing fruit when spraying in the orchard was becoming established and have seen the transition from the use of Paris green applied in a haphazard way with a bucket or barrel pump, to the use of a gasoline-driven sprayer applying a number of complex materials according to an elaborate time schedule. It is but inevitable and proper that in this rapid series of changes the chief thought has been the destruction of the pests, with little attention to the plants themselves, so long as they would survive the treatment. With the more pressing questions of pest control met, growers and investigators have been able recently to turn their attention more closely to the effects of spray materials on the plants which they were used to protect. That such effects exist and that they are in some cases harmful, in some cases beneficial, has been recognized. In fact, there has accumulated a considerable volume of data on what may be termed spray injury, the term being used to refer particularly to those forms of foliage and fruit injury generally classed as burning, yellowing and russeting. Less information is available concerning other more or

less direct influences of spray materials that are known to assume considerable importance at times.

Recent investigations by the Michigan Agricultural Experiment Station on the control of cherry leaf spot (1) have called attention to a more or less serious dwarfing of the fruit resulting from the use of certain spray applications. The problem thus raised has seemed of sufficient importance to warrant a study of the situation.

This paper presents a resume of some of the more important investigations that throw light on the matter, together with a detailed account of some experiments that deal more directly with it.

Literature Reviewed

Many reports have been made regarding the influence of spray materials on some of the more important physiological responses of plants. Of the studies made practically all have had to do with bordeaux mixture made according to various formulae.

Lodeman (2) and Harrison (3) reported that plum, peach and pear leaves were thicker when sprayed with bordeaux mixture than when left unsprayed.

Zucker (4), working with a number of greenhouse plants, found that spraying with bordeaux mixture increased the chlorophyll content of the leaves in most cases, while starch formation and transpiration were increased in all cases.

Ruth (5), published data to show that spraying primodial leaves of bean with bordeaux mixture resulted in an increased chlorophyll content per unit area and per unit fresh weight, though there was an attendant decrease in the leaf area developed.

Chuard and Porchet (6) state that spraying with bordeaux mixture increased the sugar content of mature fruits of currants and gooseberries, at the same time lengthening the growing season of the plant as measured by date of leaf fall. By injecting small quantities of copper salts into the plant they were able to hasten the maturity of the fruit. However, larger quantities proved toxic to the plant.

Ewert (7) found that potato leaves which had been sprayed with bordeaux mixture contained more starch than those on unsprayed plants. Upon subjecting the enzyme diastase to the action of a very slight trace of copper he found that it would not act upon starch. Ewert attributes the presence of starch in the sprayed leaf to the action of traces of copper on the enzyme diastase within the leaf and to represent a retarding of conduction rather than an increase in manufacture.

Among the earlier reports on the physiological effects of bordeaux spraying was that made by Rumm (8), who found that grapes sprayed with bordeaux mixture flowered earlier and also ripened their fruit earlier than those left unsprayed.

In 1912 Ewert (9) published a paper on the effect of spraying with alkaline bordeaux mixtures. Among the plants used in his experiments were currants and gooseberries. White currants sprayed with one per cent and those sprayed with four per cent. bordeaux mixtures produced sweeter fruits than unsprayed plants. Those sprayed with the one per cent. mixture gave the highest yield. In another experiment, spraying once a week throughout the season increased the sugar content of the fruit but decreased the yield as measured by weight of the berries. He reports that spraying the fruit only with a one per cent. bordeaux mixture resulted in a higher sugar content than was found in the berries either on unsprayed plants or on those having both foliage and fruit sprayed.

While conducting brown rot investigations with sweet cherries Fisher (10) noticed that some of the sprays used produced a reduction in the size of the cherries. In one orchard the reduction was so great that the fruit could not be marketed profitably. The data collected by Fisher are presented in Table 1.

Table 1. -- Average number of sweet cherries per pound 1917.

Treatment	Variety	
	Royal Ann	Black Republican
Self boiled lime-sulphur 8-8-50	127	177
Bordeaux mixture 2-4-50	128	233
Commercial lime-sulphur 1-50	111	126
Check, unsprayed	92	101

The influence of the spray materials used on the size of fruit in the Royal Anne cherry was not great. However, in the Black Republican, a variety ripening from one week to ten days later, the differences in size were more distinct.

In 1918 Fisher attempted to determine what factor was responsible for the reduced size of the fruit. In this test a number of sprays with various degrees of alkalinity were used together with a number of spreaders and other materials. He concluded that any alkaline spray had a tendency to reduce the size of the fruit. It was suggested that this influence was produced through the action of the spray material in destroying the bloom on the fruit, thereby increasing evaporation.

Frank & Kruger (11) observed that spraying potatoes with bordeaux mixture stimulated various physiological activities of the sprayed plants. The chlorophyll content of the leaf was increased, as was its length of life. Increasing the chlorophyll content was thought to be indirectly responsible for greater starch formation and storage in the tubers. The rate of transpiration was found to be accelerated when bordeaux mixture was applied.

Daggar and Cooley (12) reported potato plants sprayed with bordeaux mixture to transpire more water than plants sprayed with lime-sulphur, or left unsprayed. All sprays used that produce surface films

were found to increase the amount of water transpired. At the same time the increased water loss resulting from the use of dusts was very slight. The exact manner in which the films act to increase transpiration was not definitely determined. However, Duggar and Bonns (13) were of the opinion that the film produced when plants are sprayed acts as a spongy material, taking water directly from the interior of the leaf through some continuous water channel to the coating of spray material on the leaf surface where the evaporating area would be greatly increased. Experiments with potato, tomato, Marguerite and tobacco, showed that spraying with bordeaux mixture increased the rate of transpiration chiefly during the night. Castor bean leaves when sprayed transpired more during both the day and night than unsprayed leaves. The period of greatest water loss was the one immediately following spraying.

The work of Duggar and Cooley was later confirmed by Martin (14), who used a number of abscissed leaves of plants growing in the greenhouse. Spraying with bordeaux mixture was found to increase transpiration with all plants used except cabbage.

Butler (15) states that the effect of bordeaux on plants is one of shading; that the physiological responses produced depends on the opagueness of the spray used. When potato, tomato, Russian sunflower, and Coleus were used in transpiration tests, as measured by the rate

of transpiration for the periods before and after spraying, the water loss was increased by spraying, the greatest increase in transpiration occurring during the night.

When the lower surface of Russian sunflower leaves was sprayed the rate of transpiration was affected in the same direction as when the upper surface was sprayed.

By means of standardized cobalt chloride paper Shrieve and Martin (16) measured the rate of transpiration from tomato plants in the field. One-half of each plant was sprayed with bordeaux; the remainder was left unsprayed as a control. In all cases the rate of transpiration was found to be greatest from the parts of the plant that had been sprayed. It is also to be noted that this increase was found to occur during the day and the 24-hour period following the application of the spray material.

The literature cited reveals some of the more definite physiological responses occurring when plants are sprayed with bordeaux mixture. That spraying with bordeaux mixture increases chlorophyll development. Starch and sugar formation and transpiration are now recognized as definite facts. In one case, data have been presented which show certain reductions in the size of cherries resulting from the sprays used. There is, however, little available information regarding the

influence of spray materials on this phase of plant growth. There has not been any correlation established between the various responses produced.

Field Experiments.

Orchards Used. -- The field investigations reported in this paper cover a period of three years, 1922, 1923, 1924. The orchards under observation were located in four sections of the state and represent at least two distinct soil types.

The records for 1922 were secured from separate blocks of Montmorency and English Morello cherries used in spraying and dusting experiments for the control of cherry leaf spot. These two blocks were located on the Titus Brothers farm four miles from Traverse City. The materials used in this orchard were: Bordeaux Mixture 3-7-50 (3 pounds Copper Sulfate, 7 pounds hydrated lime and 50 gallons of water); lime-sulphur (one gallon of commercial concentrate to 40 gallons of water); sulphur dust (80% sulphur, 10% lime and 10% arsenate of lead powder); copper dust (20% copper, 10% arsenate of lead, and 70% hydrated lime). The plots were of such size as to afford convenient spraying and dusting on a scale that would give results similar to those obtained in a commercial orchard. Check trees were left in each block for comparison.

In 1923 the work was conducted in the

Titus orchard near Traverse City and in the Experiment Station orchard at East Lansing. Investigation at Traverse City was limited to the Montmorency variety; that in East Lansing was with Montmorency and English Morellos. The spray materials used in the Titus Brothers orchard were the same as those used in 1922 except that one additional plot was provided for spraying with Pyrox, and the sulphur dust was composed of 90% sulphur and 10% arsenate of lead. In laying out the plots in 1923 they were arrainged so as to cross at righ angles the plots used in 1922.

Three spray materials were used in the orchard at East Lansing. One plot was sprayed with bordeaux mixture (3-7-50). Another received commercial lime-sulphur, one gallon in 40 gallons of water, while still another plot was sprayed with 7 pounds of hydrated lime to 50 gallons of water.

In 1924 further spraying and dusting investigations for the control of cherry leaf spot were conducted in a block of five year old Early Richmond cherries growing on the farm of W. R. Roach and Company at Hart. Work in this orchard permitted observations on an earlier maturing cherry and also allowed the use of additional materials for study. The copper dust used was similar to that employed in the Traverse City orchard in 1922 and 1923. The formula for the sulphur dust was changed to 90 per cent. sulphur and 10 per cent. lead.

Two plots received bordeaux mixture as follows; one was

sprayed with a 3-10-50, and the other with a 5-5-50 mixture. Another plot was sprayed with lime-sulphur (1-40), while still another plot was treated with colloidal sulphur at the rate of 4 pounds to 50 gallons of water. Check trees were left in the sprayed part of the orchard for comparison.

Besides the work in connection with the regular experiments for controlling leaf spot, studies were made in a block of 100 Montmorency cherry trees on the farm of J. C. Maynard near Grand Rapids. The purpose of the work in this orchard was to determine the relation between the quantity of spray material on the foliage and the size of the fruit. The block was divided into four plots of equal size with a sufficient number of unsprayed trees for comparison.

The materials used were: bordeaux mixture (3-5-50); lime-sulphur (1-40); lime-sulphur (1-40, with the addition of 5 pounds of hydrated lime; colloidal sulphur (4-50).

Schedule of Sprays Used. -- In all orchards where experiments were conducted the schedule of applications recommended for the control of cherry leaf spot was followed. This schedule calls for four applications as follows: first, when the shucks are about one-half off the cherries; the second and third at two and four week intervals following number one, and the fourth application immediately following harvest. The only exceptions were in 1922 when the English Morello plots were

dusted four times before harvest and in 1933 when the Montmorency plots were dusted each week alternately from opposite sides instead of the customary full application from both sides every two weeks. In the present studies, the chief interest lies in the three applications before harvest.

Arsenate of lead powder was used at the rate of one pound to 50 gallons of material in all applications before harvest. The dusts contained ten per-cent. by weight of arsenate of lead powder.

Methods of Applying Materials -- All sprays were applied by means of power sprayers that maintained a pressure of from 225 to 250 pounds. In all orchards, except at Hart, the applications were made with a spray gun. At Hart a rod equipped with "Y" and disc nozzels was used.

In all dusting treatments the material was applied by power dusters. A Niagara machine was used in the Titus Brothers orchard, while a Dosch outfit was used at Hart. Practically all dusting was done at night or at times when conditions were favorable for dusting. When applications were made from both sides the foliage was well covered on both surfaces with a fine coating of dust particles. Approximately one pound of sulphur dust was used per tree on the Early Richmond trees at Hart. Only three-fourths of a pound of copper dust was required to give a similar covering. The Montmorency trees

at Traverse City were larger and required more material.

Rainfall -- The three years of field investigations included two seasons of heavy and one of light rainfall.

Table 2. -- Total rainfall at Traverse City, from the time the first spray was applied until the cherries were harvested, during the seasons of 1922 and 1923.

Year	Period	Rainfall
1922	May 23 to July 7.	5.81 in.
1923	June 3 to July 30	3.13 in.

In Table 2 the recorded rainfall for the Traverse City section in 1922 and 1923 is given for the period extending from the time of the first application of spray material until the fruit was harvested. The rainfall for the 1922 season was nearly double that for a similar period in 1923. Since it is generally agreed that the size of fruit depends to a considerable extent on the available moisture supply during the period in which the fruit itself is developing, it is to be expected that cherries would average larger in 1922 than in 1923. It would also seem reasonable to suppose that any factor which affects size through its influence on water supply would have a greater effect of this sort, during a dry than during a wet season.

The amount of rainfall at Grand Rapids in 1924 was similar to that at Traverse City in 1922. The

rainfall at Hart in 1924 was considered heavy for that section of the state. However, for nearly three weeks in June there was little precipitation. These data do not tell how much available moisture there was in the soil and they do not give exact information regarding atmospheric humidity. However, they afford at least a crude measure of both of these factors of environment.

Results of Field Investigations.

Results Secured in 1922 -- With the opening of an early season the first spray was applied to the plots at Traverse City on May 23. The Montmorency crop was harvested on July 17 and the English Morello by August 1. Because of an early infection of leaf spot no records could be secured from the unsprayed trees, since they had lost most of their foliage by the time the crop was harvested. The average sizes of cherries from the sprayed and the dusted plots for the two varieties are shown in Table 3. The difference in the sizes of the cherries from the various sprayed and dusted plots in the Montmorency block was not great. However, the contrast between those on the copper dusted plot and those on the plot sprayed with 3-7-50 bordeaux mixture was sufficient to attract the attention of the casual observer. The same materials when applied to the English Morello, a variety ripening two weeks later than the Montmorency, produced more striking differences. The fruit on trees sprayed with bordeaux mixture averaged 34 per cent.

smaller than those in the plot receiving copper dust. Lime-sulphur sprayed trees produced cherries intermediate between the two. Cherries of the two varieties on the dusted plots were practically the same in size.

The smaller size of English Morello cherries on the sprayed plots may be accounted for in two ways. First, this variety may be more susceptible to the dwarfing effect of the spray material. A second and more plausible possibility lies in the fact that the fruit remained on the tree longer and was exposed to the influence of the spray materials for a greater period of time. Assuming this to be true it is evident that the influence of the spray material is not altogether immediate but acts over a period of several days or weeks.

Table 3. -- Average number of cherries per pound for two varieties of sour cherry under various treatments at Traverse City in 1922.

Treatment	Varieties	
	Montmorency	English Morello
Bordeaux Mixture(5-7-50)	113	149
Lime-sulphur (1-40)	109	116
Sulphur dust (80-10-10)	102	103
Copper dust(20-10-70)	99	97

Review of Field Tests in 1923 -- The spraying season at Traverse City in 1923 was approximately two weeks later than in 1922. Following the schedule recommended for the control of cherry leaf spot the first spray was applied on June 4. The fruit was harvested July 25. A schedule of the materials used on each plot and the average number of cherries from each plot required to make a pound are reported in Table 4. Examination of these data shows that again the trees sprayed with bordeaux mixture produced the smallest cherries. When bordeaux mixture was used in combination with lime-sulphur the reduction in size was not as great as where it was used alone; however, the dwarfing was considerably greater than where lime-sulphur was used alone. Trees in the plot sprayed with pyrox, a commercial fungicide containing copper, produced slightly larger fruit than similar trees sprayed with lime-sulphur. This material, however, caused serious injury to the foliage, resulting in heavy defoliation shortly following harvest. For this reason, it would not be satisfactory for use in a commercial cherry orchard.

The two unsprayed trees produced larger fruit than that on any of the sprayed or dusted plots. This higher average may be accounted for in part by the fact that one of the trees bore cherries of an unusual size. This could not be attributed, at least entirely, to the fact that these trees were not sprayed. Had there

been more trees from which to compute an average the size might have been nearer that for the dusted plots.

Table 4. -- Average number of Montmorency cherries per pound under various treatments at Traverse City in 1923.

Treatment	Number per pound.
Bordeaux mixture (3-7-50)	181
Lime-sulphur (1-33, 1st application) Bordeaux mixture (3-7-50, 2nd and 3rd).	147
Bordeaux mixture (3-7-50, 1st application) Lime-sulphur (1-33, 2nd and 3rd)	140
Lime-sulphur (1-33)	133
Pyrox (9-50)	130
Copper dust (20-10-70)	120
Sulphur dust (80-10-10)	119
Check, unsprayed.	114

Comparison of data presented in Tables 3 and 4, showing cherry sizes under various treatments in 1922 and 1923 brings out two things: (1) cherries averaged much larger in 1922 than in 1923; (2) the dwarfing effect of certain sprays was much more pronounced in 1923 than in 1922. If the larger average size of cherries in 1922 was due to the heavier rainfall of that season, a reasonable assumption considering what is known regarding the relation of moixture supply to size of

fruit, it would seem that the relatively greater dwarfing of fruit caused by the spray materials in 1923 was in some way connected with the lower soil moisture supply or lower atmospheric humidity of that season. In other words it would seem to classify rather definitely the dwarfing influence of sprays as a water relation problem. This is in line with the conclusions reached by several investigators already cited on the influence of certain sprays on the rate of transpiration.

Three materials were used in spraying tests with two varieties of sour cherries at East Lansing in 1923. The data obtained are presented in Table 5. Bordeaux mixture (3-7-50) reduced the size in English Morello more than it did in Montmorency, a result in accord with those obtained at Traverse City in 1922. On the plot where hydrated lime alone was used in the same amount as on those plots where it was combined with copper sulfate in bordeaux mixture the reduction in size was not so great as where bordeaux was applied. It compared more closely to the reduction in size produced by lime-sulphur.

Table 5.

Average number of cherries per pound under various treatments in the College orchard at East Lansing in 1923.

Treatment	Varieties	
	Montmorency	English Morello
Bordeaux mixture (3-7-50)	180	202
Lime-sulphur (1-40)	146	177
Hydrated lime (7-50)		178
Check, unsprayed		133

Fig. I. -- Spur and fruit from a Montmorency tree sprayed four times during the season with bordeaux, taken September 12, 1923.

Continued Influence of Spray Materials on the Size of the Fruit. -- That the reduction in the size of the fruit sprayed with bordeaux mixture continues as long as the fruit remains on the tree is clearly illustrated in Figures 1, 2 and 3. These spurs were removed from Montmorency trees in the orchard at Traverse City on September 12, 1923. The crop was harvested on July 25. In this orchard, lime-sulphur did not cause any drying or shriveling of the fruit exposed to the action of the spray material for seven weeks following the harvest of the remainder of the crop. The fruit on the unsprayed trees was just as firm and well filled out as at the time of harvest.

Observations Made in 1924. -- The use of a block of Early Richmond cherries in 1924 permitted the study of a variety that ripens its fruit a few days in advance of the others studied. The first spray was applied in this orchard on June 10, followed by two others before harvest. The picking records were taken on July 26.

Since the applications in this orchard were intended primarily for the control of cherry leaf spot, standard dusts and liquid sprays were used for the most part. These were, however, supplemented by some additional materials. A list of the sprays and dusts used in this orchard is given in Table 6, together with the size of the fruit on the corresponding plots.

Fig. II. -- Spur with fruit from an unsprayed tree taken at Traverse City, September 12, 1923.

Fig. III. -- Montmorency cherries on spur sprayed with lime-sulphur four times during season;taken September 12, 1913.

Table 6. -- Average number of Early Richmond cherries under various treatments in the Roach orchard, at Hart, in 1924

Treatment	Number of cherries per pound.
Bordeaux mixture (3-10-50)	140
Bordeaux mixture (3-5-50)	136
Copper dust (20-10-70)	127
Lime-sulphur (1-40)	125
Colloidal sulphur (4-50)	122
Sulphur dust (80-10-10)	119
Unsprayed	119

Increasing the quantity of lime used in preparing the bordeaux mixture from 5 to 10 pounds, the amount of copper sulfate remaining the same, resulted in a slight increase in the number of cherries required to make a pound. However, both bordeaux sprays reduced the size of the cherries more than lime-sulphur.

In this test the plot receiving copper dust yielded smaller cherries than that sprayed with lime-sulphur. The trees in this plot were as vigorous and healthy as those in the other plots. The soil also was uniform for all plots in the orchard. The dust was applied either in the early morning or evening and at a time when conditions were very favorable for dusting.

The method of application was the same as that followed in the two preceding years at Traverse City, which gave practically the same sized fruit on both of the dusted plots.

The plot sprayed with colloidal sulphur produced cherries slightly larger than those on the lime-sulphur sprayed plot, although leaf spot control was not as good.

Relation of Density of Film of Spray Material on the Foliage to the Size of the Fruit. -- Observations made in 1923 of sprayed and dusted foliage in the Montmorency orchard at Traverse City led to the belief that the heavier the film of material on the foliage was the smaller the cherries would be. No methods were devised that would accurately measure the film of spray material on the foliage. However, photographic records were obtained of a number of sprayed leaves taken from the plots under observation, as shown in Figure 14. From these photographs a fair idea may be secured as to the amount of spray material on the foliage and the extent to which the leaf surface was covered. Comparison of the sprayed leaves in Figure 4 with the size of cherries for the respective treatments as given in Table 4 shows that bordeaux mixture produced the most obvious film of material of any of the sprays used, while at the same time it resulted in cherries of the smallest size. Lime-sulphur and pyrox, the other sprays, compared in Figure 4, did not produce

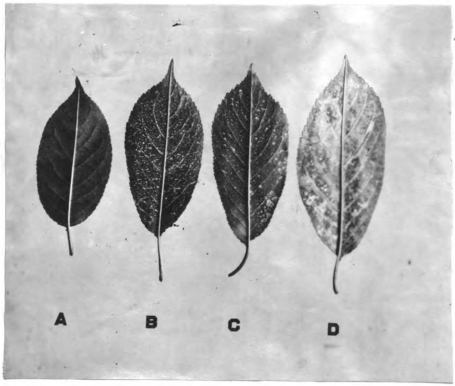

Fig. IV. -- Cherry leaves sprayed with various materials showing the film produced. A, unsprayed; B, pyrox; C, lime-sulphur; D, bordeaux mixture.

as heavy apparent coating of the leaf or as complete a coverage as did the bordeaux mixture. The size of the fruit was correspondingly larger than that on the bordeaux-sprayed plot. A similar correlation between the amount of density of film of spray material and size of fruit was observed on other plots of the orchard.

A similar comparison was made with three spray materials in the orchard at East Lansing where blocks of English Morello trees were sprayed with bordeaux mixture, lime-sulphur and hydrated lime respectively. Here again the same relation between the amount of spray material on the foliage and size of the fruit was found to exist as in the Montmorency orchard at Traverse City.

The spraying experiments at Hart in 1924 permitted further comparison of the effect of a number of materials on the amount of the film of material on the foliage and the resulting fruit size. In this orchard a comparison was made between two bordeaux mixtures, one of which contained ten pounds of lime, while the other was made with only five pounds of lime. Typical leaves from each of these plots are shown in Figure 5. The leaves sprayed with the bordeaux mixture containing five pounds of lime produced a slightly lighter film and slightly larger fruit than those on which the mixture containing ten pounds was used. With the exception of the plot receiving copper dust all plots in this orchard produced fruit of a size that was, roughly, inversely proportionate to the amount of material apparent on the

Fig. V. -- Leaves of Early Richmond cherry showing the amount of bordeaux mixture present when the quantity of lime is varied. A, ten pounds hydrated lime to three pounds of copper sulphate and 50 gallons of water; B, five pounds hydrated lime to three pounds copper sulfate in 50 gallons of water.

foliage.

More data bearing on this particular question are furnished by an experiment conducted in the Maynard orchard near Grand Rapids in 1924. The spray materials used were: bordeaux mixture (3-5-50); lime-sulphur (1-40); lime-sulphur 1-40 plus 5 pounds of hydrated lime); colloidal sulphur (4-50). Check trees were left at convenient places in the orchard to give a fair average for unsprayed trees. The first spray was applied on June 6; it was followed by two others, on June 20 and July 8 respectively. The fruit was harvested on July 23. The average number of cherries to the pound in each plot are shown in table 7.

Table 7. -- Average number of Montmorency cherries per pound under various treatments in the Maynard orchard, at Grand Rapids, in 1924.

Treatment	Number of Cherries
Bordeaux mixture(3-5-50)	108
Lime-sulphur(1-40 plus 5 lbs. hydrated lime)	100
Lime-sulphur (1-40)	94
Colloidal sulphur (4-50)	91
Unsprayed.	90

Owing to heavy rainfall throughout the early part of the season and frequent rains until harvest, the cherries on all plots were larger than in

any of the other ochards studied. The differences, however, were similar ~~in order~~ to those recorded for the preceding years with the same and with other varieties. Bordeaux mixture prepared with 5 pounds of hydrated lime retained its position in its dwarfing effect on the fruit. The use of five pounds of hydrated lime to each 50 gallons of the lime-sulphur spray did not reduce the size of the fruit as much as the bordeaux mixture but it did diminish the size more than the use of lime-sulphur alone. Colloidal sulphur resulted in very little decrease in the size of the fruit. The addition of five pounds of lime to the lim-sulphur solution did not leave the heavy deposit on the leaf surface characteristic of the bordeaux mixture. However, the entire leaf surface was covered with a light film. Lime-sulphur alone covered less of the foliage than did either of the other two sprays just mentioned. The presence of colloidal sulphur on many of the leaves could not be detected by the eye, while on other leaves a slight deposit of material was visible near the margins of the leaf; this gradually faded away a short distance from the margin.

Detail Studies in Orchard and Laboratory. -- In order better to determine the reason for the dwarfing of the fruit, studies were made of detached branches from English Morello trees in the sprayed plots in the orchard at East Lansing in 1923. A description of the sprays used has been given in

connection with Table 5.

Effect of Spray Materials on the Rate of Wilting -- At 1:00 P. M. on July 1 uniform lots of shoots were removed from each of three plots and taken to the laboratory where they were spread out on a table to wilt. The temperature of the room at this time was 78 degrees F. Notes were taken at intervals during the afternoon and the following morning as to the condition of the leaves. The data collected are shown in Table 8. The leaves on the branches with fruit attached did not wilt as rapidly as did those on the shoots with cherries removed. From this it may be concluded that the leaves were drawing water from the fruit, due to the difference in osmotic concentration in these two parts, as has been shown by the work of Chandler (17). In the series where the fruit was left attached to the branches, the order of wilting as shown by the turgidity of the leaves was: bordeaux first, lime-sulphur second, and unsprayed last. The leaves on both shoots sprayed with bordeaux mixture had dried at the end of 16 hrs. until they could be broken when crushed in the hand.

Rate of Water Loss when Wilting. -- A similar series of shoots was secured on July 2, taken to the laboratory where they were exposed to the air under the same conditions as those on the previous day. Each branch was weighed hourly during the day to determine the rate at which drying occurred. At the close of the test the areas of all the leaves on each shoots were measured

Table 8. Notes on the rate at which detached cherry branches wilted under laboratory conditions, July 1, 1923.

Treatment	Time allowed for wilting.						
	30 min.	1 hr.	1-1/2 hr.	2 hr.	3-1/2 hr.	5 hr.	16 hr.
1 Unsprayed no fruit	Leaves slightly wilted	Wilting rapidly	Leaves and stems wilted	No changes	Condition unchanged	Leaves wilted	Leaves wilted
2 Lime-sulphur (1-40) no fruit	Leaves showing some wilting	Wilting rapidly.	Stems showing wilting	No change.	Little change.	Same as check	Leaves wilted
3 Bordeaux (3-7-50) no fruit	Leaves fresh.	Leaves show wilting	Leaves slowly wilting	Wilting rapid.	Leaves and stem wilted	Leaves begin to dry.	Leaves dry
4 Unsprayed with fruit	Leaves fresh.	Leaves fresh.	Leaves fresh.	Leaves fresh.	Fruit wrinkled	Leaves fresh.	Leaves slightly wilted
5 Lime-sulphur (1-40) with fruit	Leaves fresh.	Leaves fresh.	Leaves fresh.	Leaves fresh.	Leaves show wilting	Wilting slow.	Leaves wilted
6 Bordeaux (3-7-50) with fruit	Leaves fresh.	Leaves fresh.	Leaves fresh.	Leaves wilted.	Leaves wilted; fruit wrinkled.	Shoot dry wilted.	Leaves dry

with a planimeter, the rate of wilting being calculated per unit of leaf area. The data collected are graphically represented in Figures 6 and 7.

It should be noted that the unsprayed branches wilted after the first hour at a slower rate until 2:30 P. M. than either of those that had been sprayed. After this time they showed a uniform rate of water loss above that of the sprayed branches. Bordeaux-sprayed branches did not wilt as rapidly for the first hour but for the next few hours the rate was much greater. From this it may be deduced that such spray materials as bordeaux mixture in some way reduces the ability of the leaf tissues to retain water and resist drying. It should be noted also that the two sprayed branches without cherries in Figure 4 reached a zero point in wilting at 5:30 P. M.; from that time on the weight increased slightly. This increase in weight may have been due to greater relative humidity and the absorbtion of atmospheric moisture by the leaf tissues.

Measurement of the Amount of Water Transpired from Sprayed and Unsprayed leaves. -- Since it was impossible to measure accurately the quantity of water transpired from trees growing in the orchard and treated in various ways, shoots were removed from the trees under observation. The first lot were cut at 9:00 A. M. on July 2, care being exercised to obtain shoots that were uniform from the standpoint of the position in which they grew on the tree and the number of leaves present. The

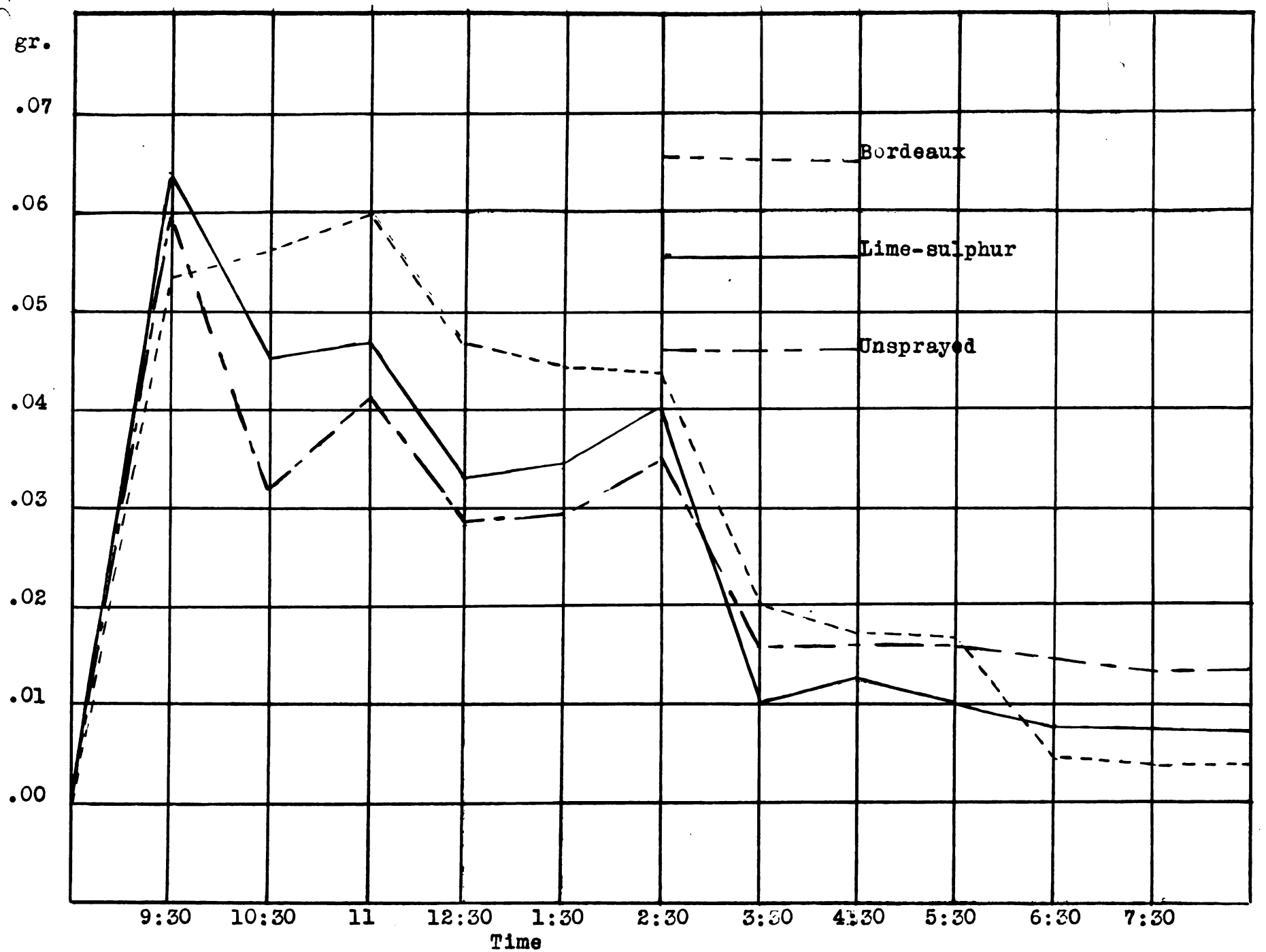

Fig. III. -- Graphs showing rate of water loss from cherry branches with fruit attached, sprayed with different materials, when cut from the tree and exposed in a warm room.

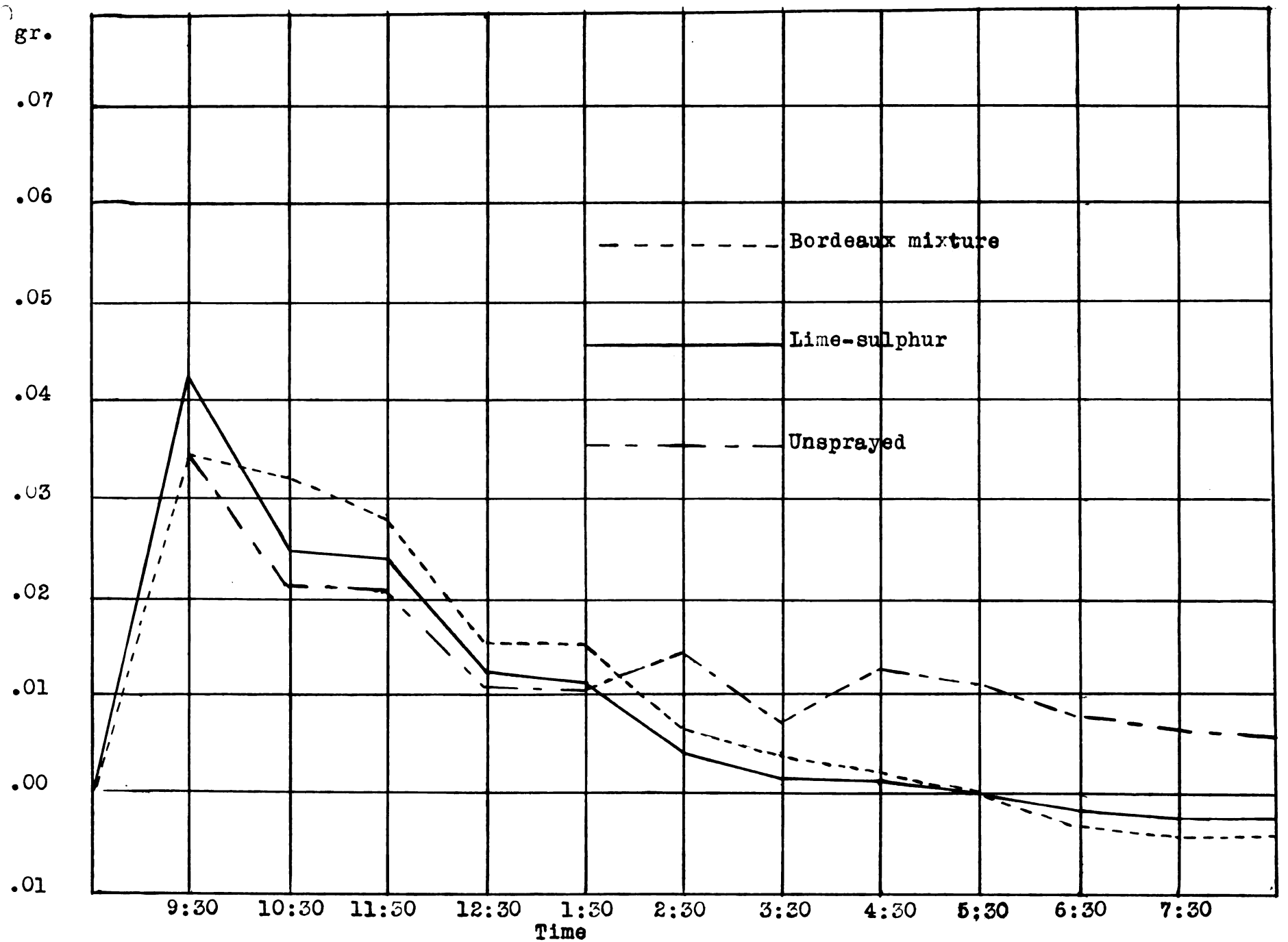

Fig. VI. -- Rate of water lossin grams per hour from sprayed cherry branches when wilting.

shoots were taken to the laboratory where buds were cut under water and immediately sealed in graduated glass cylinders containing tap water. When all were ready they were removed to a bench in an open space outdoors, where the exposure to sunlight and wind was similar to that in the orchard. Readings were made at frequent intervals during the day showing the amounts transpired by the leaves of the various lots. After a 48-hour period, the final reading was made and leaf area measured for each shoot. The data obtained are recorded in Table 9. Spraying with bordeaux mixture or lime-sulphur solution increased the quantity of water transpired over that of unsprayed shoots. It is also evident that branches with cherries attached took up more water per unit of leaf area than did those whose fruit had been removed. A duplicate test starting at 11:00 A. M. and closing at 6:00 P. M. on July 5 gave similar results.

Table 9. -- Transpiration water loss in c.c. per unit of leaf from detached cherry shoots for a 48-hour period from 9:00 A. M., July 2 to 9:00 A. M. July 3, 1923.

Treatment	Condition	Leaf Area sq. in.	Water loss in c.c.	Water loss per unit of leaf area.
Bordeaux mixture	Without fruit	26.4	58	2.19
Lime-sulphur	" "	25.9	52	2.01
Unsprayed	" "	26.5	52	1.96
Bordeaux mixture	" "	21.9	62	2.83
Lime-sulphur	" "	26.5	67	2.54
Unsprayed	" "	23.1	55	2.25

The greater water intake of the shoots bearing fruit might conceivably be due to greater transpiration by the leaves or by the fruit or it may be due to the retention of water by the fruit. To secure some indication as to which of these factors is operative, two sets of branches were selected from each of the plots under observation at East Lansing. These were similar to those used in the previous test, but the terminal leaf-bearing wood was removed in this case. The twigs were set in graduated glass cylinders as before. In one lot the fruit was dipped in warm paraffine to prevent loss of water from the surface of the fruit while the others were left untreated. All shoots bore the same number of cherries of about the same size and degree of maturity. All were exposed to atmospheric conditions similar to those in the orchard for a 48-hour period and the amount of water taken up was then calculated per cherry. A study of the data presented in Table 10 shows that branches with uncoated cherries took up over four times as much water as those whose fruit was protected with paraffine. This would indicate that water was being evaporated from the fruit in large quantities. It will also be noted that when they were sprayed with bordeaux mixture or lime-sulphur the water loss was much greater than in those on which no spray was applied. However, all the water taken up was not transpired as is shown in the figures for the cherries dipped in paraffine, but it was used to supply an apparent

deficit within the fruit at the time it was removed from the tree.

Table 10. Amount of water taken up per cherry by shoots bearing green fruit. Data represents a 48-hour period starting at 8 A. M. July 5, 1923.

Treatment	Cherries paraffined	Cherries unparaffined
	c.c.	c.c.
Bordeaux mixture	.43	1.78
Lime-sulphur	.15	.78
Unsprayed	.06	.57

It has been pointed out that under conditions of water stress within the plant there is evidence of a withdrawal of water from the fruit to the leaves to replace that which is being transpired. Some measure of the rate of this movement of water from the fruit to the leaves was obtained by injecting a concentrated solution of lithium nitrate into green cherries on trees in each of the plots under observation. Leaves adjacent to the fruit were removed at intervals and preserved for spectroscopic examination of the ash for the presence of lithium. Some of the records that were obtained are presented in Table 11. Evidently, the presence of bordeaux mixture on the foliage hastened the movement of water from the fruit to the leaves. The movement was slower where lime sulphur was used but not as slow as where no

Table 11. -- Rate at which water moves from the fruit to the leaves when sprayed with bordeaux mixture and lime-sulphur, and when unsprayed tree, as shown by the lithium test.

Time allowed after treatment	Spraying treatment	Leaves				
		First	Second	Third	Fourth	Fifth
30 minutes	Bordeaux mixture	Trace	Trace	-	-	-
	Lime-sulphur	-	-	-	-	
	Unsprayed	-	-	-	-	
1 hour	Bordeaux mixture	+	+	Trace	Trace	
	Lime-sulphur	Trace	-	-	-	
	Unsprayed	-	-	-	-	
2 hours	Bordeaux mixture	+	+	-	Trace	
	Lime-sulphur	+	-	Trace	-	
	Unsprayed	-	-	-	-	
3 hours	Bordeaux mixture	+	+	+	Trace	-
	Lime-sulphur	+	+	Trace		
	Unsprayed	-	-	-	-	-
5 hours	Bordeaux mixture	+	+	+	-	-
	Lime-sulphur	+	Trace	-		
	Unsprayed	Trace	+	-	-	

spray was used. Further evidence of the movement of water from the fruit to the foliage was observed in the time required to show foliage injury from the lithium injected into the cherries. On a clear hot day in July lithium injected into the fruit was found to kill adjacent leaves sprayed with bordeaux in 12 hours. Those sprayed with lime-sulphur succumbed after 30 hours, while on unsprayed trees the leaves showed only slight injury after 48 hours.

Direct Influence of Spray Material on the Fruit. -- In the orchard at East Lansing a number of English Morello cherries on the trees in the plot sprayed with bordeaux mixture were protected from the spray material at the time each application was made by covering with paper bags, to determine if possible, any direct influence of sprays on the size of the fruit. The leaves adjacent to the protected fruit received the same amount of spray material as did other parts of the tree. At harvest the protected fruits were weighed and comparison made with unprotected fruits, fruits from the same trees, and also fruits from unsprayed trees.

Table 12. -- Weight of cherries with diverse methods of applying bordeaux mixture in the college orchard, 1923.

Treatment	Wt. of fruit, gms.
Leaves and fruit sprayed usual way	2.2
Leaves only, fruit protected	2.6
Leaves and fruit unsprayed	3.4

The average weights per cherry for each of the treatments are presented in Table 12. Spraying the foliage alone reduced the size of the fruit 23 per cent.; spraying the fruit and foliage reduced the size of fruit 35 per cent. It would appear therefore, that though there is a direct dwarfing influence of the spray material on the fruit itself, the major share of the dwarfing is brought about through the influence of the spray on the rate of water loss from the leaves.

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Summary

After three years of investigation of the influence of various dusts and spray materials on the size of fruit in the sour cherry the following conclusions seem warranted:

(1). All sprays used reduced the size of the fruit in comparison with fruit from unsprayed trees. The reduction in size was greatest in dry years.

(2). Dusted trees produced fruit slightly smaller than unsprayed trees. With one exception the fruits on copper and sulphur dusted plots were almost the same in size.

(3). English Morello, a late ripening variety, was more susceptible to dwarfing than Montmorency, a variety that ripens two weeks earlier.

(4). Of the various sprays used, bordeaux mixture was found to produce the greatest reduction in the size of fruit. Lime-sulphur caused some reduction, while the addition of 5 pounds of hydrated lime to 50 gallons of lime-sulphur spray reduced the size of the fruit still more than the lime-sulphur alone.

(5). Some evidence was obtained that there is a relationship between the density of the film left by certain spray materials and the reduction in the size of the fruit.

(6). The dwarfing of the fruit caused

by bordeaux mixture does not stop with the ripening of the fruit, but continues to act until the fruit dries on the tree.

(7). Transpiration tests with sprayed branches from trees in the orchard show that bordeaux mixture and lime-sulphur increase transpiration. The greatest increase was in those sprayed with bordeaux mixture.

(8). That water moves from the fruit to the foliage under conditions of high transpiration and water deficit within the plant has been noted. This is probably correlated with the smaller fruits in dry years on trees sprayed with bordeaux mixture.

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