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THE EFFECT OF SPRAYS ON THE
PHOTOSYNTHETIC
ACTIVITY OF SOUR CHERRY LEAVES

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THE EFFECT OF SPRAYS ON THE PHOTOSYNTHETIC
ACTIVITY OF SOUR CHERRY LEAVES

by

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INTRODUCTION

During the past thirty years, Michigan has become the leading sour cherry producing region in the United States. The rise of this industry was due largely to favorable soil and environmental conditions. To maintain this rank as a leading state, the growers are confronted with the ever important problem of controlling cherry leaf spot (Coccomyces hiemalis). Previous to the past few years, the growers have used either lime-sulfur or bordeaux mixture to control leaf spot in a four-spray program. The results were, however, none too satisfactory; lime-sulfur failed to give control in epidemic years, and bordeaux, while giving good control of leaf spot, resulted in a decreased size of fruit and at times serious defoliation of trees due to copper injury.

In view of the fact that adequate control with lime-sulfur was not obtained in some years and that bordeaux resulted in the production of smaller fruit, some new spray materials have been introduced to control leaf spot, these being the new low-soluble copper compounds. Within the past five years, results obtained at the Michigan Experiment Station revealed these new copper compounds to be superior to either of the old standard sprays, and consequently, some of these compounds are now recommended by the Station.

That certain sprays have a deleterious effect on the trees, both chemically and physically, has been proved conclusively. It is difficult to obtain a spray that is innocuous to the trees and at the same time one that is successful in controlling the disease or insect for which it is intended. With the advent of these new copper compounds,

questions arose as to the effect of these new sprays on the metabolic processes going on continuously within the plant. How would they affect transpiration, respiration, and the assimilatory activity of the leaves? The purpose of this study was to reveal the effects these sprays have on the photosynthetic behavior of the sprayed cherry leaves.

REVIEW OF LITERATURE

The studies made on the photosynthetic activity of sour cherry trees are very limited, and apparently no direct quantitative determinations have been carried on. The investigations of this general type previously reported and dealing with deciduous fruits have been made largely with apple trees grown in greenhouses.

Hoffman (12) found that lime-sulfur, when applied to McIntosh apple trees growing in the greenhouse, reduced the photosynthetic activity 37 per cent. However, this harmful effect disappeared completely two weeks after application. Hoffman (13) further observed that lime-sulfur when applied to orchard grown apple trees reduced the photosynthate produced. The reduction was greater under conditions of high temperatures and these high temperatures also resulted in more marginal burning of the leaves.

Christopher (3) reported that flotation sulfur caused a reduction in carbon dioxide assimilation of orchard grown trees, but that the reduction was not nearly as serious as that caused by lime-sulfur. Thus he concluded that flotation sulfur was a safer spray to use in controlling fungous diseases on apple trees.

By enclosing entire trees in glass assimilation chambers, Heinicke (11) studied the effect of lime-sulfur sprays on the foliage. His

results showed that lime-sulfur did reduce carbon dioxide assimilation temporarily but the trees regained their efficiency within ten days. He concluded that while some sulfur burning of the leaves was evident, this in no way could account for the reduction in photosynthetic activity, but that lime-sulfur in some way reduced the assimilation rate of normal healthy leaves.

The effects of sulfur sprays on McIntosh and Baldwin apple leaves at various temperatures with controlled humidity were studied by Hyre (16). His results revealed that lime-sulfur effected twice the reduction in photosynthetic activity as did wettable sulfur. Hyre also applied lime-sulfur to the lower surface only and to the upper surface only of leaves and found that leaves which were sprayed on the lower side only showed a reduction in photosynthesis comparable to that of normally sprayed leaves. However, spraying leaves only on the upper side resulted in but slightly reduced photosynthesis.

From the data reported above, it appears that lime-sulfur as well as other forms of sulfur reduces carbon dioxide assimilation of apple trees, although the reduction is not as marked with wettable and flotation sulfur as with lime-sulfur. The apparent reduction in photosynthesis could in part be accounted for by an increased rate of respiration. Hoffman (15), however, carried on respiration tests on leaves sprayed with lime-sulfur and stated that increased respiration from lime-sulfur did not account for the marked net reduction in photosynthate.

Though no oil sprays were used in this study, it is of interest to note the effect of oil sprays on photosynthesis. Young (30), Hoffman (14),

and Schroeder (25) all reported that oils reduced the carbon dioxide intake of leaves. This reduction was usually greater with increased viscosity and increased percentages of oil in the spray. The trees did, however, gradually recover from the effects of the oil but the recovery became less with each succeeding application of spray.

The effect of calcium arsenate in combination with different buffers on the carbon dioxide intake of Jonathan apple leaves was studied by Overholser and Overley (18). They found that three sprays of calcium arsenate and "safeners" applied at 14-day intervals did not adversely affect the leaves, as measured by the carbon dioxide intake. In case the spray materials themselves might have absorbed some carbon dioxide and in this way masked any reduction in leaf activity, sprayed pieces of cardboard gave results comparable to air checks.

Hoffman (12) included bordeaux mixture in his studies with apple trees and reported that bordeaux sometimes caused a slight reduction in carbon dioxide intake while at other times there was no reduction. He was of the opinion that any reduction was due to some physical effect of the bordeaux precipitate rather than to a chemical disturbance like that of lime-sulfur since the leaves regained their former efficiency when the spray material was washed from them.

Clore (5) applied bordeaux mixture, copper sulfate, and lime as separate sprays to Delicious apple leaves. His results revealed that bordeaux and copper sulfate alone did not reduce carbon dioxide absorption when compared with the check trees. Lime, however, did reduce carbon dioxide absorption. Clore stated that at the time of sampling, the leaves were so well covered with spray that the green

color of the leaves was not visible except upon close observation.

Childers (2) sprayed tomatoes with bordeaux mixture, oil, and a combination of bordeaux and oil. His data showed that under drought conditions, bordeaux-sprayed tomatoes showed a marked reduction in plant growth, yield, and size of individual fruits. The combination oil-bordeaux spray showed similar results, but they were not so striking. The oil sprays failed to decrease size or yield of tomatoes and even increased terminal growth. Childers suggested that the increased growth may be due to the oil's lowering transpiration and as a result, the plants had more water for growth.

Upon running carbon dioxide assimilation tests on tomatoes, Christopher (4) reported that bordeaux and lime used alone failed to reduce carbon dioxide absorption. A copper sulfate solution caused visible spotting of leaves and as a result of this injury, a marked reduction in carbon dioxide absorption.

Rasmussen (23) analyzed sour cherries for their total solids content. The indices which he obtained indicated that the total solids content of lime-sulfur-sprayed cherries was 3-5 per cent lower than that of bordeaux-sprayed cherries. Furthermore, the lime-sulfur-sprayed cherries ripened later than did the bordeaux-sprayed cherries, while the bordeaux-sprayed cherries were smaller than those sprayed with lime-sulfur.

From the above literature review, one is not justified in stating the effects of bordeaux on leaf activity. It is apparent, however, that bordeaux mixture is not as toxic to leaf metabolism as is lime-sulfur. Since bordeaux-sprayed cherries are smaller in size but at

the same time are higher in total solids content, one would suppose that bordeaux has little effect in depressing the photosynthetic rate of cherry leaves. The work of Hoffman, Clore, Childers and Christopher have indicated this in other genera. A hypothesis advanced might be that bordeaux has more influence on transpiration than on the photosynthetic activity.

MATERIALS AND METHODS

Trees. The trees selected for the study were five-year-old Montmorency cherry trees, vigorous in growth and uniform in size. On April 27, three-fourths of a pound of ammonium-sulfate was applied to each tree, being distributed as uniformly as possible around each tree. Five different plots made up of four trees in each were laid out, and the blossoms were removed from all trees on May 3. Deflorating was done to insure uniform samples.

Sprays. The five different plots were sprayed as follows: Liquid lime-sulfur ($2\frac{1}{2}$ gallons per 100), Cupro K (3 pounds per 100 gallons), Coposil (3 pounds per 100 gallons), bordeaux mixture (6-8-100), and checks.

Liquid lime-sulfur was used in this study because it is one of the old standard sprays used to control leaf spot. Frequently, lime-sulfur is used as a basis for comparison when any new material enters the market. Most of the studies made on the effect of sprays on trees have dealt with lime-sulfur, and in most cases, lime-sulfur has been found to reduce the assimilatory activity of the leaves. Rasmussen (21) reported that lime-sulfur sprayed trees have foliage superior to bordeaux-sprayed trees, but that lime-sulfur did not control leaf spot

in epidemic years.

Cupro K was used in the studies because it was one of the first low soluble copper compounds used for the control of leaf spot in Michigan. It gave satisfactory control of leaf spot according to Cation (1) and caused little if any dwarfing of the fruit according to Rasmussen (23). Cupro K is a copper oxychloride containing 25 per cent metallic copper and is manufactured by the Rohm and Haas Company, Philadelphia, Pa.

Coposil was used in the experiment because it was found to cause less injury than any of the bordeaux mixtures [Rasmussen (23)]. Coposil is a copper ammonium silicate containing 20 per cent metallic copper and 4 per cent metallic zinc and is manufactured by the California Spray Chemical Corporation, Richmond, California.

A 6-8-100 high-calcium lime bordeaux was used because it has been recommended as a fungicide for the control of leaf spot on sour cherry trees but was discontinued since it caused serious dwarfing of the fruit and premature defoliation of trees under Michigan conditions.

The remaining plot was used as a check and received no spray applications during the study.

The four-spray program, as recommended by the Michigan Experiment Station, was followed in this work [Rasmussen, Hutson and Cation (24)]. This program consists of four applications: petal-fall, when most of the petals have dropped; two-weeks application, should be completed within two weeks after petal-fall; four-weeks application, should be completed two weeks after application two; after-harvest, just after the fruit is harvested. The petal-fall spray was applied May 13, the

two-weeks spray May 30, the four-weeks spray June 14, and the after-harvest spray July 18.

All sprays were applied with a 6-gallon-a-minute pump delivering 4-5 gallons per minute at the nozzle with a pressure of 300 pounds. The trees were covered as completely, uniformly, and timely as was possible.

Discussion of Methods. No completely satisfactory method for determining photosynthetic activity has been presented. A little understanding of what takes place within the plant during photosynthesis along with the other plant processes that are going on simultaneously is all that is needed to see why the above statement is obvious. As Miller (17) pointed out, photosynthesis is no simple reaction but a series of such and any results that are obtained in measuring photosynthesis will depend on what place in this series of reactions the data were obtained.

Of the methods employed to measure photosynthesis, the following are the most used: (a) carbon dioxide absorption, (b) liberation of oxygen, (c) saccharification, and (d) dry weight accumulation. Since no one of these methods measures the same thing, it is no wonder that conflicting results are obtained.

Coincident with photosynthesis are the processes of respiration and translocation which render photosynthesis determinations difficult. According to Miller (17), photosynthesis is the absorption of carbon dioxide and formation of carbohydrates with the release of oxygen, and respiration is the absorption of oxygen and the subsequent breaking down of carbohydrates with the liberation of carbon dioxide. Thus, it is apparent that no two methods will yield the same results.

Most of the work reported in the review of literature was done with the carbon dioxide absorption method as described by Heinicke and Hoffman (9). Briefly, this method is based on the fact that green leaves in the presence of light absorb carbon dioxide from the air. The amount of carbon dioxide in the incoming and in the outgoing air is accurately determined and the difference is regarded as apparent photosynthesis for that given leaf area.

Another much-used method of measuring the photosynthetic activity is the dry weight increment method. According to Miller (17), this method was first used by Sachs in 1884. With a few modifications, the method today is essentially that which Sachs used. He removed one-half of a leaf blade at the beginning of the experiment, obtained the dry weight, and later removed the second half of the leaf and obtained its dry weight. The increase in dry weight during this time represented the photosynthate produced during the day. Sachs recognized that this was not a true figure since translocation and respiration were in no way considered. Thus Sachs added to this day gain the night loss and considered this to be respiration and translocation. This method is not entirely correct since it assumes that respiration and translocation proceed at the same rate during the day as they do at night and this supposition is not exactly true.

The method was improved according to Miller (31) when Ganong in 1908 devised a punch which could remove a definite leaf area (one square centimeter). The use of this punch enabled one to obtain more uniform samples since large veins and midribs can be omitted from the samples. Ganong was of the opinion that the removal of these punches did not interfere with the normal functioning of the leaves.

The main sources of error in the dry weight method, according to Thoday (28), are: (1) the shrinkage in the area of leaves during the day, (2) the asymmetry of leaves used in sampling. Thoday considered the method satisfactory for rates of increase greater than two milligrams per square decimeter per hour. He insisted, however, that the results were not comparable to results obtained by the gasometric methods since they did not measure the same things. Thoday (29) later reported that apparently translocation occurs during the day as well as during the night.

Spoehr (27) considered the dry weight method none too reliable. He likened this means of measuring what goes on in a leaf during the day to the business carried on in a bank. One is not justified in assuming that the difference in total accounts from morning till night is any more of an index to the total transactions concurred at a bank during the day than to assume the same for plant leaves.

Thus any method used to measure photosynthesis is not going to be entirely satisfactory. The results will have to be taken as relative and not final. Pickett (19) demonstrated this by comparing three methods of measuring photosynthetic activity. He found that the dry weight increment method gave the highest results, followed by the absorption tower method, and the saccharification method gave the lowest results. He concluded that each method can be criticized and the data obtained are relative and not absolute.

Sampling. For the present studies, the dry weight increment method was employed since field results were desirable and this method offered the simplest means for obtaining such results. The absorption tower method involves considerable expense to be set up in the orchard

and since many samples were to be taken, the dry weight method was deemed the most desirable.

The punch used in the study removed an area of 0.3144 square centimeters from each leaf. This is considerably smaller than the square centimeter punch used by Ganong in 1908 and Miller (17), nevertheless, it was found in the present studies that a smaller punch could remove more uniform samples by omitting large veins.

All samples were taken from leaves on spurs of the previous season's growth located on the median portion of the shoots. Leaves on spurs at the apex of the shoots and leaves on spurs at the base of the shoots were found to vary considerably and as a result were not used in the studies. Cowart (6) had previously reported that the photosynthetic activity was greater at the apex of the shoot than at the base.

Two trees were studied under each treatment. A sample consisted of 30 punches, one punch being taken from each of 30 different leaves. Samples were taken thrice daily: at 5:30 a.m., 2:00 p.m., and 7:00 p.m. The increase in dry weight during the day was obtained by subtracting the weight of the 5:30 a.m. sample from either the 2:00 p.m. sample or the 7:00 p.m. sample, depending upon which was the greater. Assuming that translocation and respiration proceed at the same rate during the day as during the night, the loss in dry weight during the night was added to the day gain to secure the total photosynthate produced during the day. Six samples were taken from each leaf, and this constituted a run which lasted for two days. Consequently, a new run was started every two days.

Since it was not practical to obtain a uniform deposit of spray material on all leaves, it was necessary to remove this spray material immediately preceding sampling. This was done by washing only the area taken as a sample. At the start of the study, the washing was done with a weak acid solution, but this resulted in a burning of the leaves apparently by the liberation of metallic copper. During the remainder of the study, the leaves were washed with distilled water.

Immediately following collections, all samples were placed in glass vials which were tightly stoppered. As soon as all samples were taken, they were brought to the laboratory, weighed, dried in an oven at 90° C. for 24 hours by which time they reached a constant weight. They were then removed, placed in a desiccator, cooled, and weighed again. The weights were recorded and calculations were to be made later.

After the samples had been weighed a second time to obtain their constant dry weight, they were placed in crucibles and ash determinations were made. Thoday (29) reported that changes in dry weight may consist, in part, of ash to as much as 5 per cent. Furthermore, it was next to impossible to remove all the spray residue from the leaves and since the 6-8-100 bordeaux ash weighed the most and had the greatest deposit of copper throughout the studies, it may be assumed that by correcting for ash, this source of error was eliminated. No quantitative determinations were made, however, to support this assumption.

The crucibles were placed in a muffle furnace for 12 hours at a temperature of 400° C. The crucibles were removed, and ash weights were recorded. The weights for the ash were then subtracted from the constant dry weights to give the net dry weight. It was these net dry

weights which were used to compute the photosynthetic activities for the various treatments.

Only healthy leaves were used in these studies. No injured leaves were included in the samples. Thus, it should be pointed out that this study does not pertain to the entire tree since, following the first spray application, many copper injured leaves fell to the ground and in this way were lost to the tree. Such was not the case with lime-sulfur; no injury resulted from its use in any of the sprays.

PRESENTATION OF DATA

Dry weight determinations for a period of six days were made on eight trees before any spray materials had been applied. These were made to see if any significant differences existed in the photosynthetic rates of the leaves before starting differential treatments. The data for these determinations are presented in Table 1. It would appear that trees C and E had a photosynthetic rate significantly less than the remaining trees, but the mathematical analysis did not bear this out. By analysis of variance, it was shown that no significant differences existed among the averages for the eight trees before any spray was applied.

Since each treatment was applied to two trees, all the data hereafter presented are on the basis of the daily averages of the two trees in each plot. The data in Table 2 present the average photosynthate produced each day before any spray material had been applied. Again the figures show that no significant differences existed in the photosynthetic efficiency of the trees.

In Table 3, data are presented showing the average amounts of photosynthate produced by the leaves of the two trees in each plot after the first spray application. The leaves of the bordeaux-sprayed trees had a photosynthetic rate significantly less than the leaves of all other treatments, and the average rate of the leaves of the Cupro K-sprayed trees was significantly less than that of the check trees. Furthermore, the rate of the bordeaux-sprayed leaves was significantly (highly) less than the rates of the lime-sulfur-sprayed and check leaves (Table 4).

The lime-sulfur-sprayed leaves with a daily average of 8.01 gms of dry matter produced were significantly less efficient than the check and Cupro K-sprayed leaves after the second spray application. The photosynthetic rate of lime-sulfur-sprayed leaves, when compared to the rate of the Coposil-sprayed leaves, was a border line case and no conclusions can be drawn from these data. There was no significance between the photosynthetic activity of the bordeaux-sprayed leaves and of leaves of the other treated plots (Tables 5 and 6).

The data, presented in Table 7, are for the photosynthate produced by the leaves of the trees after the third spray had been applied. From the data in Table 8, it can be stated that the mean for the lime-sulfur-sprayed leaves was significantly (highly) less than the means of the check, Cupro K-sprayed, and bordeaux-sprayed leaves. The Coposil-sprayed leaves had a mean significantly (highly) less than the mean of the Cupro K-sprayed leaves. The mean of the bordeaux-sprayed leaves was significantly less than the mean of the Cupro K-sprayed leaves, and the mean of the Coposil-sprayed leaves was significantly less than the mean of the check leaves.

The summaries for the total photosynthate produced by the leaves of the trees after three applications are presented in Table 9 and the mathematical analysis is given in Table 10. The leaves of the trees sprayed with lime-sulfur had a mean significantly (highly) less than the means of the check and Cupro K-sprayed leaves. The lime-sulfur mean was also significantly less than the Coposil mean. The means of the Coposil-sprayed leaves and the bordeaux-sprayed leaves were significantly (highly) less than the means of the check and Cupro K-sprayed leaves.

After dry weight determinations had been made for the first three sprays, the leaves on spurs on the median portion of the previous season's shoots were depleted, and in order to insure uniform samples, leaves for further sampling had to be obtained from new trees. As previously mentioned, four trees were laid out in each plot, so two new trees were available for further study, but no determinations had been made on these trees previous to spraying, and thus it was desired to have some data on these trees before the fourth spray was applied.

Dry weight determinations were run for eight days before the fourth spray was applied. The data are presented in Table 11 and the analysis is given in Table 12. Significant differences existed among the trees and as a result the data obtained after the fourth spraying can be compared only with those obtained from the same trees previous to this spraying.

In Table 13 are presented figures on the photosynthate produced by the leaves of the trees after the fourth spray was applied. By comparing the data in Table 13 with those in Table 11, it is obvious that the means of the check, bordeaux-sprayed, Coposil-sprayed and

Cupro K-sprayed leaves were higher after the fourth spray was applied than before and that the mean of the lime-sulfur-sprayed leaves was considerably lower. Thus, this further substantiates the hypothesis that lime-sulfur reduces the photosynthetic rate toward the latter part of the season.

From these data it is apparent that lime-sulfur applied as a spray to cherry leaves early in the season did not reduce the photosynthetic rate of the leaves. However, following its second application, lime-sulfur did reduce the photosynthetic activity materially, though the leaves appeared to regain their former efficiency within a three-day period. Following the third spray, the photosynthetic activity was reduced considerably and this time the leaves did not appear to regain their former activity within eight days. Following a fourth application, the photosynthate produced was reduced, but this reduction, much like that following the second application, lasted only four days, after which time the leaves appeared to function normally.

The bordeaux-sprayed leaves showed a marked reduction in photosynthate produced following the first spray. The leaves did not appear to recover from this injurious effect. Following the second application, the photosynthetic rate was likewise reduced, though the reduction was too small to be of any significance. The same can be said of the third spray. After the fourth spray, the bordeaux-sprayed leaves actually increased their photosynthetic activity; however, this increase in photosynthate produced was general with all treatments, and this can not be attributed to any stimulatory action of the spray.

Spraying with Coposil did not result in a decrease in the ability of leaves to synthesize food materials following the first or second application. However, following the third application, rate of photosynthesis was significantly lower than in the case of Cupro K-sprayed or check leaves. After the fourth spray, the leaf efficiency increased, though this was not, apparently, due to any influence of the spray material.

The Cupro K-sprayed leaves showed a reduction in photosynthate produced following the first spray application, but during the remainder of the season the leaves functioned normally in this respect.

It is not surprising that (6-8-100) bordeaux in the first application materially decreased the photosynthetic rate of the leaves, for observations at that time showed that copper injury was evident. The lower surfaces of the sprayed leaves were bronzed and the leaves had a tendency to curl slightly toward the dorsal surface.

Copper injury was accentuated by weather conditions immediately following the first spray application. At that time, unsettled, cloudy days with considerable rainfall prevailed. Such conditions are not conducive to sulfur injury as pointed out by Dutton (7), and may explain the fact that lime-sulfur-sprayed leaves did not show decreased photosynthetic efficiency.

Table 1. Total photosynthate produced per day by leaves of unsprayed trees. Expressed as grams per square meter leaf area.

Date	Trees							
	A	B	C	D	E	F	G	H
May 7	8.67	13.88	11.04	12.08	7.75	15.79	11.88	12.62
May 8	6.47	12.19	8.59	14.11	6.89	18.00	10.08	10.08
May 9	7.10	9.12	4.33	4.24	5.18	2.65	6.47	8.90
May 10	7.73	8.70	5.48	8.06	5.40	3.08	3.67	8.37
May 11	8.49	6.68	2.44	5.94	5.10	0.42	3.48	9.36
May 12	4.57	7.95	0.63	6.05	2.33	3.18	0.62	6.27
Total	43.03	58.52	32.51	50.48	32.65	43.12	36.20	55.60
Mean	7.17	9.75	5.42	8.41	5.44	7.19	6.03	9.27

Table 2. Average total photosynthate produced per day by leaves of the two trees in each plot previous to spraying. Expressed as grams per square meter leaf area.

Date	Treatment				Temperature		Character of day
	Cupro K	Coposil	6-8-100	Lime-sulfur	Maximum	Mean	
May 7	11.28	11.56	11.77	12.25	89	78	partly cloudy
May 8	9.33	11.35	12.45	10.08	82	76	partly cloudy
May 9	8.11	4.29	3.92	7.69	84	75	clear
May 10	8.22	6.77	4.24	6.02	84	72	cloudy
May 11	7.59	4.19	2.76	6.42	79	72	partly cloudy
May 12	6.26	3.34	2.76	3.45	84	74	partly cloudy
Total	50.79	41.50	37.90	45.91			
Mean	8.47	6.92	6.32	7.65			

Table 3. Total photosynthate produced per day by leaves after first spray application. Average of two trees in each plot; expressed as grams per square meter leaf area.

Date	Treatment					Temperature		Character of day
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur	Maximum	Mean	
May 20*	13.58	11.72	15.27	9.28	13.43	72	68	cloudy
May 24	8.91	10.02	10.77	5.25	9.76	82	68	partly cloudy
May 25	6.36	9.97	7.85	3.08	6.23	89	76	partly cloudy
May 27	12.56	9.24	15.99	11.50	13.90	80	74	cloudy
May 28	7.63	9.57	12.52	7.37	11.98	84	75	partly cloudy
May 29	10.33	10.56	11.34	10.80	11.18	80	70	clear
Total	59.37	61.08	73.74	47.28	66.48			
Mean	9.90	10.18	12.29	7.88	11.08			

*Although the first spray was applied May 13, no determinations were made until May 20 because weather conditions would not permit sampling at that time.

Table 4. Analysis of variance of total photosynthate produced per day by leaves after first spray application.

Source	Degrees of freedom	Sum of squares	Variance	F	Standard error
Total	29	245.81			
Treatment	4	63.58	15.90	6.31**	
Days	5	131.79	26.36	10.46**	
Error	20	50.44	2.52		1.59

**Significant at the one per cent level.

In order for the difference between two means to be significant, the difference should be 1.92 at the 5 per cent level and 2.62 at the 1 per cent level.

Table 5. Total photosynthate produced per day by leaves after second spray application. Averages of two trees on each plot; expressed as grams per square meter leaf area.

Date	Treatment					Temperature		Character of day
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur	Maximum	Mean	
May 30	12.02	12.67	11.51	10.60	6.90	84	72	partly cloudy
May 31	11.86	9.74	9.33	7.42	7.22	80	72	cloudy
June 1	12.19	11.02	10.81	7.27	6.90	78	66	cloudy
June 2	6.05	8.70	8.71	7.91	8.16	73	64	partly cloudy
June 3	5.83	6.57	4.41	4.40	5.79	77	64	partly cloudy
June 7	12.74	11.78	11.46	8.38	8.59	67	61	partly cloudy
June 8	12.37	11.72	9.12	9.75	7.48	67	58	partly cloudy
June 9	8.70	7.54	15.21	15.17	12.14	76	62	clear
June 10	9.76	7.75	8.48	9.50	8.33	78	70	cloudy
June 13	11.98	10.39	10.61	13.67	8.59	73	60	clear
Total	102.50	97.88	99.65	94.07	80.10			
Mean	10.25	9.79	9.97	9.41	8.01			

Table 6. Analysis of variance of total photosynthate produced per day by leaves after second spraying.

Source	Degrees of freedom	Sum of squares	Variance	F	Standard error
Total	49	319.02			
Treatments	4	32.50	8.13	2.20	
Days	9	153.00	17.00	4.59**	
Error	36	133.52	3.71		1.93

**Significant at the one per cent level

In order for the difference between two means to be significant, the difference should be 1.75 at the 5 per cent level and 2.35 at the 1 per cent level.

Table 7. Total photosynthate produced per day by leaves after third spray application. Average of two trees in each plot; expressed as grams per square meter leaf area.

Date	Treatment					Temperature		Character of day
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur	Maxi-mum	Mean	
June 14	14.05	10.55	11.88	9.86	5.04	76	64	cloudy
June 15	11.99	7.52	11.56	10.39	7.89	84	72	partly cloudy
June 16	7.85	2.75	6.20	6.52	4.98	69	65	cloudy
June 20	13.52	5.52	13.36	11.92	6.75	83	70	clear
June 21	13.47	6.95	10.71	14.68	5.36	84	72	cloudy
June 22	8.48	9.38	8.80	6.62	6.23	85	72	partly cloudy
June 23	7.37	6.91	6.63	5.72	3.84	86	74	clear
June 28	9.97	8.43	6.79	7.94	7.21	72	60	clear
June 29	10.81	8.06	7.05	4.18	4.61	75	62	partly cloudy
Total	97.51	66.07	82.98	77.83	51.91			
Mean	10.83	7.34	9.22	8.65	5.77			

Table 8. Analysis of variance of total photosynthate produced per day by leaves after third spraying.

Source	Degrees of freedom	Sum of squares	Variance	F	Standard error
Total	44	388.22			
Treatments	4	132.33	33.08	8.99**	
Days	8	138.15	17.27	4.69**	
Error	32	117.74	3.68		1.92

**Significant at the one per cent level

In order for the difference between two means to be significant, it must be 1.84 at the 5 per cent level and 2.48 at the 1 per cent level.

Table 9. Summary of total photosynthate produced by leaves of trees after three spray applications (from May 7 to June 29).

Application	Treatment				
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur
First	59.37	61.08	73.74	47.28	66.48
Second	102.50	97.88	99.65	94.07	80.10
Third	97.51	66.07	82.98	77.83	51.91
Total	259.38	225.03	256.37	219.18	198.49
Means	10.38	9.00	10.25	8.77	7.94

Table 10. Analysis of variance of summary of total photosynthate produced after three applications.

Source	Degrees of freedom	Sum of squares	Variance	F	Standard error
Total	124	1041.11			
Applications	2	69.07	34.54	13.65**	
Treatments	4	107.16	26.79	10.59**	
Days	22	422.94	19.22	7.60**	
Application x treatment	8	119.64	14.96	5.91**	
Error	88	322.29	2.53		1.59

**Significant at the one per cent level

In order that two means be significantly different, the difference between the two means must be 0.89 at the 5 per cent level and 1.18 at the 1 per cent level.

Table 11. Total photosynthate produced per day by leaves of new trees before the fourth spray was applied. Average of two trees in each plot; expressed as grams per square meter leaf area.

Date	Treatment					Temperature		Character of day
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur	Maximum	Mean	
July 6	8.80	7.05	7.57	17.06	16.48	65	56	clear
July 7	7.59	8.54	9.33	13.84	14.37	67	53	partly cloudy
July 9	5.99	7.90	6.31	11.03	9.13	49	46	cloudy
July 10	5.03	7.16	1.75	3.61	3.35	62	52	partly cloudy
July 14	4.36	12.45	11.78	10.12	9.91	54	50	cloudy
July 15	6.17	9.75	8.13	8.16	9.06	58	52	cloudy
July 16	4.23	10.44	10.02	14.84	10.02	68	55	clear
July 17	1.37	8.37	10.86	10.44	9.86	60	52	cloudy
Total	43.54	71.66	65.75	89.10	82.18			
Mean	5.44	8.96	8.22	11.14	10.18			

Table 12. Analysis of variance of total photosynthate produced by new trees previous to fourth spray application.

Source	Degrees of freedom	Sum of squares	Variance	F	Standard error
Total	39	513.37			
Treatments	4	154.14	38.53	5.87**	
Days	7	175.51	25.07	3.82**	
Error	28	183.72	6.56		2.56

**Significant at the one per cent level

In order for the difference between two means to be significant, the difference should be 2.60 at the 5 per cent level and 3.51 at the 1 per cent level.

Table 13. Total photosynthate produced per day by leaves of trees after fourth spray application. Average of two trees in each plot; expressed as grams per square meter leaf area.

Date	Treatment					Temperature		Character of day
	Cupro K	Coposil	Check	6-8-100	Lime-sulfur	Maximum	Mean	
July 18	5.79	13.58	9.97	16.62	11.50	65	57	cloudy
July 19	0.32	7.53	6.63	8.94	6.56	78	68	cloudy
July 20	5.35	10.44	12.36	13.62	6.52	67	61	cloudy
July 21	3.28	2.12	10.03	10.91	4.66	62	56	cloudy
July 22	11.77	14.15	15.16	15.90	9.91	66	57	partly cloudy
July 23	11.62	11.77	12.99	13.78	10.50	59	56	cloudy
Total	38.13	59.59	67.14	79.77	49.65			
Mean	6.36	9.93	11.19	13.30	8.28			

DISCUSSION

The results obtained in this study are in the main in accord with those reported by other investigators. Temporary significant differences were found in the photosynthetic rates of leaves sprayed with various materials. However, the reduction in the photosynthate produced did not last during the entire period of the study, and in the case of lime-sulfur-sprayed trees, the leaves usually regained their former efficiency in three to eight days.

Though statistically significant differences were found among the several treatments studied, other factors are obviously of more importance in the functioning of cherry trees and their subsequent production of good crops than the influence of spray materials on photosynthetic efficiency. Among the more important of such factors are: vigor of the tree, weather conditions, soil types, fertilization, pollination and fruit setting. Evaluation of fungicides commonly used in the cherry orchard should be on the basis of their efficiency in control of diseases and their effect on fruit size through their influence on transpiration, rather than on the basis of any considerable influence on photosynthesis.

SUMMARY

A study of the effects of certain fungicides on the photosynthetic activity of sour cherry leaves showed:

1. That lime-sulfur did not reduce photosynthesis after the first spray had been applied, but did reduce the photosynthate produced after the second, third and four spray applications. The leaves apparently recovered from the effect of the spray three, eight and four days respectively after it had been applied. The reductions were great enough, however, so that highly significant differences resulted from the use of the spray. The toxic effect became more evident with each succeeding application.
2. That 6-8-100 bordeaux significantly reduced the photosynthate produced as a result of the first spray application, but during the remainder of the season, though some reduction in photosynthesis was evident, the reduction was not significant.
3. That Cupro K significantly reduced the photosynthetic activity of the leaves following the first spray. Coposil-sprayed leaves showed no significant reduction at this time. Following the second, third, and fourth spray applications, Cupro K-sprayed leaves showed no reduction in the photosynthate produced. Likewise, Coposil, though followed by some reduction in leaf activity following the second and fourth spray, did not significantly reduce photosynthesis. However, after the third spray, Coposil did significantly reduce the photosynthate produced. Thus it appears from this study that the new copper compounds are superior to lime-sulfur from the standpoint of photosynthetic efficiency.

4. In view of the fact that the reductions in photosynthetic activity were only temporary and not continuous throughout the season, it is evident that sprays for the control of leaf spot on sour cherry leaves should be selected more on a basis of their fungicidal value, of their apparent injury to the foliage, and of their effect on transpiration, than of their effect on photosynthesis.

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