

**The Effect of Certain Spraying Materials on
the Abscission of Fruit and Foliage of
the Apple and Sour Cherry**

THESIS

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**By
Walter Curtis Dutton
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THESIS

Introduction

The prevalence of fungus diseases and insect pests is responsible for the use of fungicides and insecticides on fruit plants. It is evident, then, that the first consideration in selecting a spraying material is that it shall be effective in pest control. However, there are other factors that must be considered and an important one is the question of foliage injury.

Foliage injury has been recognized and discussed as long, perhaps, as plants have been sprayed. The literature of spraying contains many references to spray injury and among them are excellent descriptions of various types of injury, studies of the components of spraying materials that cause or retard injury and of environmental factors that favor its development.

A complete review of the literature with a bearing on spray injury will not be attempted here but a brief discussion of some of the work which has a direct application to the studies to be reported in this paper may well be included.

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Review of Literature

Crandall (3)* has described two types of bordeaux injury on apples: -- "Brown-spotting" and Yellowing". He states that the brown-spotting is the more common but less serious form of injury as leaves are not entirely destroyed by it as when affected by yellowing. The yellowing frequently caused serious injury but could not be definitely connected with any particular set of environmental conditions. Crandall (3), Hedrick (5), Adams (1), and others all agree that moisture, as rain, fog or dew, must be present in order for bordeaux injury to develop, the usual observation having been that injury generally follows a rainy period or develops most seriously in rainy seasons.

Hedrick (5) and Adams (1) state that the degree of injury is in proportion to the amount of copper sulphate in the bordeaux. Pickett (10)

*Reference is made by number to "Literature Cited" pp. 135-136.

observed that the amount of foliage injury seemed to be directly proportional to the number of applications. Hedrick (5), Adams (1), Cooper (4), Crandall (3) and others state that bordeaux injury cannot be prevented or even reduced to any degree by the use of excess lime. Crandall's work, however, indicated that after-applications of milk of lime would reduce injury, though Cooper (4) and Pickett (1) were unable to get any benefit from such treatments.

Yellowing or the yellow-leaf type of bordeaux injury may occur, according to Adams (1), within two weeks after the application and subsequent defoliation may continue with any protracted wet period. Crandall (3) found that yellowing was more likely to occur in June and July than either earlier or later. Hedrick (5) concluded that less injury is likely to develop when bordeaux is applied in dry weather.

Lime-sulphur Injury. Injuries to foliage caused by lime-sulphur have not been studied so extensively as those caused by bordeaux but

there are a few valuable contributions. Saftro (11) found that the true lime-sulphur injury is due primarily to the calcium polysulphides and to a less extent to the calcium thiosulphate and that any other compounds (referring to original ingredients or decomposition products of lime-sulphur) present either before or after applications are harmless. Young (16) has found that lime-sulphur is strongly alkaline when applied and then changes to a slightly acid condition. Wallace (14) concluded that the action of lime-sulphur in causing injury differs fundamentally from that of bordeaux. Lime-sulphur injury, he believes, is caused before the solution has dried on the tree and while it is still very caustic. That copper sulphate used in combination with lime-sulphur is unsafe is indicated by the work of Morse (9) who found that the combination caused severe foliage injury and russetting of the fruit. Thatcher and Streeter (13) state that when acid lead arsenate is mixed with lime-sulphur solution, a definite chemical change

takes place forming some lead sulphide and arsenate of lime and that such change probably increases the danger of foliage injury. The addition of hydrated lime, casein and other materials retard this change and should consequently reduce foliage injury.

Injury by spraying materials frequently occurs seriously on leaves that have been injured mechanically, by insects or by fungi, particularly apple scab. In such instances, spray injury occurs when otherwise there probably would be none. Such injury has been observed and reported by Wallace (14), Crandall (3), Cooper (4), Morse (8), and Whetzel (15). It has been caused by various materials -- lime-sulphur, bordeaux, lead arsenate, sulphur-lead dust and copper dust. The toxic material evidently penetrates the leaf through the break in the cuticle and epidermis caused by the previous injury, and then spreads out through the leaf tissues, the leaf showing a circular or irregular brown area somewhat larger than the original fungal or mechanical lesion.

Weather and Foliage Injury. --

The conditions which make the leaf more resistant or more susceptible to foliage injury by various materials have not been well established. In this connection, Wallace (14) found little evidence to show that wet weather during or following application of the spray (lime-sulphur) very materially favors foliage injury but did think that the nature of the season previous to spraying might influence the leaf structure in such a way that it might be resistant or susceptible to lime-sulphur injury. Hedrick (5) has stated that it seems reasonable to suppose that leaves and fruit have less resistant power against the action of copper poisons when wet weather prevails than during dry weather and offers in support of this the statements of Kohl (6) that "cuticle is much thinner when the plant is grown in moist atmosphere"; of Lothelier (7) that "it (the cuticle) may entirely disappear when grown in a saturated atmosphere; and of Bain (2) that remarkable differences are found in the cuticle of the apple and peach leaves

in accordance with the weather. Bain's conclusions were that exposure to any atmospheric conditions that have a tendency to increase transpiration, results in an increased thickness of cuticle.

Abscission of Fruit. -- Another angle of spray injury which has received attention only recently is that of abscission of fruit following the use of certain spraying materials. Sanders (12) discusses this in some detail. He reports experiments beginning in 1915 in Nova Scotia, in which the use of lime-sulphur as a summer spray has definitely reduced the quantity of apples produced and that the same thing was reported from British Columbia in 1919. The size of fruit from lime-sulphur sprayed trees was smaller than with bordeaux. He gives evidence to show that changing from lime-sulphur to bordeaux or copper-lime dust resulted in a large increase in production in the Annapolis Valley, and also found that lime-sulphur applied to the fruit alone or to the upper surface of leaves caused no abnormal drop of fruit but where lime-sulphur was

applied to the under surface of the leaves that most of the apples dropped and concludes that the damage is the result of absorption of lime-sulphur through the under surface of the leaf. This injury, he found, did not result from preblossom applications of lime-sulphur and only a limited amount from the calyx application but when applied in the two-weeks application, the fall of fruit was always heavy.

Object of Investigations. -- A study of the reports of investigations just cited brings out some very interesting facts and, although some forms of injury and the degree to which they may develop have been recognized, together with some of their contributing factors, the literature still leaves much doubt as to the actual amounts of leaf-fall that may be expected to occur with a given material with various fruits and different weather conditions. More complete information is desirable with regard to the conditions under which injury occurs and to the relation of environmental factors to resistance or susceptibility of leaves to injury

as well as the influence of tree vigor to the development of injury. Furthermore, the comparative susceptibility of various kinds of fruit to injury by different materials has not been completely established.

The investigations reported in this paper were planned and carried through to obtain information along the lines just mentioned, with special reference to conditions prevailing in Michigan.

Presentation of Data.

The studies reported in this paper were made in connection with a number of individual experiments with apples and cherries at various places in Michigan. A description of each individual experiment will first be given with a statement of materials, strengths, methods of application, methods of obtaining records and a tabular statement of results, without discussion. A general discussion will then follow, bringing together and

discussing comparable material from the individual experiments. In connection with this discussion will be considered some of the environmental conditions and factors which probably have had a direct bearing on the results.

Various materials will be mentioned in the description and discussion of the several experiments and in order to avoid a complete explanation in each instance the following definition of terms is inserted. Lime-sulphur, unless otherwise specified, refers to the standard, commercial liquid concentrate testing 32 to 33 degrees Beaume. Bordeaux, refers to a mixture of copper sulphate, lime and water. The formula is usually given, as 8-8-100. The first figure always refers to copper sulphate (pounds), the second to lime (pounds), and the third to water (gallons). The kind of lime used will usually be given in parenthesis. Lead arsenate means ordinary commercial lead arsenate powder without spreader. Where lead arsenate paste was used it will be mentioned as such. The statement of dilutions of lime-sulphur, lead arsenate, etc., as 3 gals. in 100,

2 lbs. in 100, or 2-100 mean that the number of gallons or pounds of material mentioned were mixed with enough water to make 100 gallons of spray.

Types of Injury. Preliminarily to the description of the experiments and the discussion of the results it seems desirable to describe and define certain types of injury that may be referred to rather frequently.

Injuries Resulting from the Use of
lime-sulphur Alone or in Combination with Acid
Lead Arsenate. -- When lime-sulphur and acid lead arsenate are used together on apples two types of injury may occur. The first will be referred to in this paper as the "yellow-leaf" type of injury and it is generally conceded that this injury is caused by water soluble forms of arsenic which result from the reaction between lime-sulphur and acid lead arsenate. This injury, in the early stages, appears as brown spots. These may be few or many in number and may vary in size from very small to one-quarter inch or more in size. The leaves gradually turn yellow, due to the loss of chlorophyll, and abscise. When this type of injury develops the leaves usually reach the yellow stage in one week to ten days or possibly two weeks

after an application of lime-sulphur and lead arsenate and so far as the writer has observed, there is no recurrence of this injury until after another application of spray.

The other type of injury resulting from the use of lime-sulphur and lead arsenate will, in this paper, be referred to as the "brown leaf" or "scald" type of injury and is undoubtedly caused by the lime-sulphur itself and therefore might occur when lead arsenate is not used with the lime-sulphur. With this, there are no definite lesions but a portion of the leaf, usually the tip or a margin where the material has concentrated before drying, is killed. If the injury is severe the entire leaf may be killed or when it is only slight there may simply be a few spots anywhere on the leaf. Areas killed in this way are frequently invaded by saprophytic fungi. Just how this injury occurs is not well understood but may possibly be correlated with the fact that lime-sulphur is strongly alkaline before it dried. The same or at least, similar types of injury occur under widely

different conditions, first when the lime-sulphur on the foliage dries very slowly and second, when lime-sulphur is applied to foliage when the temperature is high. In the first, it may be assumed that the lime-sulphur remains strongly alkaline until it dries and thus the period during which injury might occur is greatly extended. On the other hand, with high temperature it may be that the process of injury is accelerated by the high temperature.

Lime-sulphur will often cause rather serious injury to apple leaves that bear deep seated scab lesions, the lime-sulphur penetrating into the leaf and spreading out through the leaf tissues through the scab lesions. The portion of the leaf killed by the lime-sulphur is brown and the brown area is usually circular in form and larger than the original lesion. This type of injury may not cause defoliation, but frequently does when severe.

Bordeaux Injury. -- Bordeaux is responsible for different types of injury to the foliage and fruit of trees as described by Crandall

(3) but only one type will be considered in this paper as having been responsible for foliage abscission in the apple and cherry. This is the form generally referred to as the "yellow leaf" bordeaux injury. This is first evident as small purplish spots on the surface of the leaf, these spots soon turn brown and the leaf begins to turn yellow, the green color usually disappearing last from immediately around the brown lesions. Leaves injured in this way, particularly those of the cherry, closely resemble cherry leaves affected by leaf-spot. In fact, close examination is usually necessary to differentiate between the effects of bordeaux injury and cherry leaf spot.

Experiment 1.

Defoliation by Lime-sulphur and Bordeaux in Montmorency and English Morello Cherries, 1923. An orchard of Montmorency and English Morello cherries on the College grounds at East Lansing was used in 1923 to compare lime-sulphur and bordeaux in their effect on leaf-fall. The trees were 14 years old, under cultivation and in fair vigor.

Material and Applications. Two materials only were used, lime-sulphur and bordeaux, and at the following strengths.

1. Lime-sulphur, 3 gal. in 100.
2. Bordeaux, 8-14-100 (hydrated lime).

Lead arsenate powder, 2 lbs. in 100, was used with both for all applications. The spraying was done with a spray gun and with about 275 pounds pressure. The schedule and dates of applications follow. 1. Petal-fall, May 29;
2. Two-weeks, June 8; and 3. Four-weeks, June 24.

Each material was used regularly for all applications except that a few trees in the lime-sulphur plot were sprayed with bordeaux at the two-weeks application.

Record of Leaf-fall. Leaf counts were made five times and recorded on tags attached to the spur or shoot in question. Spur leaves were recorded on Montmorency, and shoot leaves on English Morello trees as they produce very few spurs under ordinary conditions. The counts were made at the following dates. June 5, July 11, August 13, September 7 and October 4.

The October 4 leaf count was not made on the lime-sulphur sprayed trees of English Morello due to severe infestation by leaf-spot with the consequent defoliation. This was the result of omitting the after-harvest application. The September 7 count was not made in the Montmorency trees that were sprayed alternately with lime-sulphur and bordeaux. The data for both varieties are presented in Table 1.

Table 1									
Various									
1.0	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001
0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001	0.0005
0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001	0.0005	0.0002
0.1	0.05	0.02	0.01	0.005	0.002	0.001	0.0005	0.0002	0.0001
0.05	0.02	0.01	0.005	0.002	0.001	0.0005	0.0002	0.0001	0.00005
0.02	0.01	0.005	0.002	0.001	0.0005	0.0002	0.0001	0.00005	0.00002
0.01	0.005	0.002	0.001	0.0005	0.0002	0.0001	0.00005	0.00002	0.00001
0.005	0.002	0.001	0.0005	0.0002	0.0001	0.00005	0.00002	0.00001	0.000005
0.002	0.001	0.0005	0.0002	0.0001	0.00005	0.00002	0.00001	0.000005	0.000002
0.001	0.0005	0.0002	0.0001	0.00005	0.00002	0.00001	0.000005	0.000002	0.000001

Experiment 2.

The Relation of Various Spraying and Dusting Materials to Leaf-fall in the Montmorency Cherry, Traverse City, 1923. Records were obtained at Traverse City in 1923, in connection with extensive leaf-spot control experiments, to determine the amount of defoliation caused by several spraying, and dusting materials when used for the regular summer treatments on the Montmorency cherry. This work was done in the Titus Brothers orchard about four miles north of Traverse City. The trees were mature, growing on sandy soil and under thorough cultivation and generally in good vigor. The trees from which the records were taken in 1924 had been uniformly treated in 1923. There was practically no leaf-spot in 1924 so that the study of leaf-fall in relation to spray injury was in no way complicated by the effects of leaf-spot.

Schedule of Applications and Materials. The regular summer spraying schedule was used. The various applications were made at the following dates.

1. Petal-fall, June 4 and 5.
2. Two-weeks, June 18 and 19.
3. Four-weeks, July 3.
- 3a. Special. July 10. Dusts only.
4. After-harvest. July 27.

For applications 2 and 3 the dust applications were split and one side of trees dusted one week earlier than the date indicated for those applications. This constituted half applications on alternate sides of the trees at intervals of one week rather than complete application at intervals of two weeks. The spraying applications were completed each time at the period indicated.

The spraying materials were applied with a spray gun with 250 to 275 pound pressure. The dusting was done with a large power duster.

The materials and the strengths at which they were used were as follows: --

1. Lime-sulphur, 3 gal. in 100,
and lead arsenate, 2 lbs. in 100. All applications.
2. Bordeaux, 6-10-100 (hydrated

lime), and lead arsenate, 2 lbs. in 100. All applications.

3. Lime-sulphur, 3-100, for application 1, 2 and 4, and bordeaux, 6-10-100, for application 3. Lead arsenate used with both materials.

4, Bordeaux, 6-10-100, for application 1, lime-sulphur, 3-100, for applications 2, 3 and 4. Lead arsenate used with both materials.

5. Pyrox, 18 lbs. in 100. All applications.

6. Copper dust, 20% monohydrated copper sulphate, 10% lead arsenate, and 70% hydrated lime.

7. Sulphur-lead dust, 90% sulphur and 10% lead arsenate.

8. Check, no treatment.

Leaf-fall Records. Leaf counts were made on shoots at three periods as follow: June 15, July 20, September 10.

The record of defoliation is presented in Table 2.

Table 2.

Materials and Strengths	Recon
	Trees
Lime-sulphur, 3-100, and lead arsenate, 2-100	4
Bordeaux, 50 10-100, and lead arsenate, 2-100	4
Lime-sulphur, 3-100, for Nos. 1, 2, and 4, bordeaux, 6-10-100, for No. 3.	4
Bordeaux, for No. 1, lime- sulphur for Nos. 2, 3 and 4.	4
Pyrox, 18-100	4
Copper dust, (20%), lead arsenate, 10%	4
Sulphur-lead dust, 90-10	4
Check	2

Experiment 3.

Defoliation by Lime-sulphur and Bordeaux in the Montmorency Cherry, East Lansing, 1924. The comparative test of lime-sulphur and bordeaux in the College orchard made in 1923 on Montmorency and English Morello was repeated, with slight changes, on Montmorency in 1924.

Materials and Applications. The two materials, lime-sulphur and bordeaux, were used as follows:

1. Lime-sulphur, 3 gal. in 100.
2. Bordeaux, 6-6-100 (lump lime).

Lead arsenate was used with both for all applications.

They were applied according to the regular four application schedule and at the dates here indicated. 1. Petal-fall, June 5; 2. Two-weeks, June 18; 3. Four-weeks, July 2; 4. After-harvest, August. 20.

Record of Leaf-fall. Leaf counts were made at four periods and recorded on tags

in the usual way. Spurs were used. The counts were made as follows: June 20, July 15, August 20, and October 4.

The record of defoliation appears in Table 3.

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PAGE 1

Experiment 4.

The Relation of Tree Vigor to Susceptibility to Bordeaux Injury in the Montmorency Cherry, Traverse City, 1923. In 1922 at Traverse City a number of materials were used for the control of cherry leaf-spot, some of which gave good results and others very poor so that some trees lost very few leaves and others were badly defoliated. In 1923 a plot sprayed with bordeaux ran across all the plots of 1922, so that trees that had been defoliated in varying degrees in 1922 received uniform spraying treatment with bordeaux in 1923. Other phases of management, as cultivation, fertilization and pruning were uniform.

The bordeaux was applied according to the regular four application schedule consisting of the petal-fall, two-weeks, four-weeks and after-harvest applications. The bordeaux was made according to the 6-10-100 (hydrated lime) formula.

Records of Leaf-fall. The comparative amounts of defoliation were determined by counting the number of leaves persistent on shoots

on September 12 and at the same time recording the number of leaves that had dropped by counting the leaf-scars. These records were obtained from one group of trees which, in 1922 had lost very little foliage and from another group which in 1922 had lost about 75% of the leaves by mid-summer. The results of these counts are presented in Table 4.

Table 4. The Relation of Vigor to Susceptibility
to Bordeaux Injury in the Montmorency Cherry,

Traverse City, 1923.

Condition of the trees in 1922.	No. Shoots Examined	Original No. Leaves (Aver.)	No. Leaves Persistent Sept. 12 (Aver.)	Leaf- Fall.
Badly defoliated	201	9.5	8.1	1.4
Slightly defoliated	197	9.4	8.4	1.0

Experiment 5.

The Relation of the Vigor to Susceptibility to Bordeaux Injury in the Early Richmond Cherry, East Lansing, 1924. In 1924 a group of 12 Early Richmond trees in the College orchards at East Lansing were used to study the relation of tree vigor to the development of bordeaux injury. The trees were of mature age, in low vigor and had been making very short terminal growth and forming very few spurs.

Treatment in 1924. Just before the blooming period in 1924 six of the twelve trees were given a heavy application, 5 pounds per tree, of nitrate of soda. This was broadcast under the trees and well beyond the spread of the branches. There were frequent rains so that it was quickly taken into the soil. The other six trees were left without any nitrate.

Cultural treatments and spraying were uniform for both lots. They were all sprayed four times according to the regular summer schedule which included the petal-fall, two-weeks, four-weeks and

after-harvest applications. 6-6-100 bordeaux (lump lime) and lead arsenate, 2 lbs. in 100, were used for all applications.

The application of the nitrate of soda resulted in a greatly increased growth, -- the shoot growth was greater, the leaves were larger, thicker and darker green in color.

Record of Leaf-fall. The leaf-fall records were obtained from terminal shoots as the trees had been in such low vigor that very few spurs had been formed. Leaf counts were made at five periods as follows: June 28, July 25, September 4, and October 5.

The data are presented in Table 5.

Experiment 6.

The Effect of Shading, Method of Application, and Materials on the Abscission of Leaves of the Apple, East Lansing, 1923. A block of young trees of Bladwin and Red Canada on the College grounds at East Lansing was used in 1923 to determine the relation of several factors to the abscission of leaves. These trees had been planted four years at the beginning of the experiment and were in good vigor but not bearing fruit. Information along several lines was desired in connection with this experiment, among which were the relation of shading, the portion of the leaf covered with spraying materials, and of several materials and different strengths of materials to leaf-fall.

Materials and Strengths. Three materials and the strengths at which they were used were as follows: --

1. Lime-sulphur, $2\frac{1}{2}$ gal. in 100.
2. Bordeaux, 8-8-100 (lump lime).
3. Bordeaux, 6-10-100, (lump lime).

4. Sulfocide, 1 to 150.

5. Check, no treatment.

The materials were all applied with a good bucket pump, using a fine vermorrel nozzle. No arsenate of lead was used.

Details of Methods and Treatments.

Three methods of application and a check as follow, were used.

1. Upper surface only of leaves sprayed.
2. Lower surface only of leaves sprayed.
3. Upper and lower surfaces both sprayed.
4. Check, no spray.

The trees were divided into approximate quarters for each treatment listed and when the spraying material was being applied oiled sheets were used to prevent the spray from reaching the limbs where it was not desired. With certain materials only one method of application was used, --

complete coverage of both upper and lower surfaces -- and in such instances one-half the tree was sprayed and the other half used as a check.

With lime-sulphur, certain trees were left fully exposed to light and sunshine, one was semi-shaded, and a third was fully shaded. Shading as used here means the exclusion of direct sunlight only. The shading designated as "semi-shade" was accomplished by supporting over and around the tree screens made of lath with the inter-spaces equal to the width of the laths. The so-called "full-shade" was accomplished by supporting over and around the tree a cover of heavy white muslin.

Some difficulty was encountered in applying the sprays to leaves that were to be sprayed on the underside only as it is obviously impossible to spray the undersurface of the leaf without some spray going on up and falling on the upper surface of adjacent leaves. It was also difficult when spraying the upper surface only to prevent some material from getting on the lower side. In an effort to avoid these difficulties the actual dosage in either case was probably less than on the same surface of leaves which were completely

covered above and below.

Dates of Application and Leaf-counts.

The trees were sprayed three times as follows:

1. May 29; 2. June 8; 3. August 16.

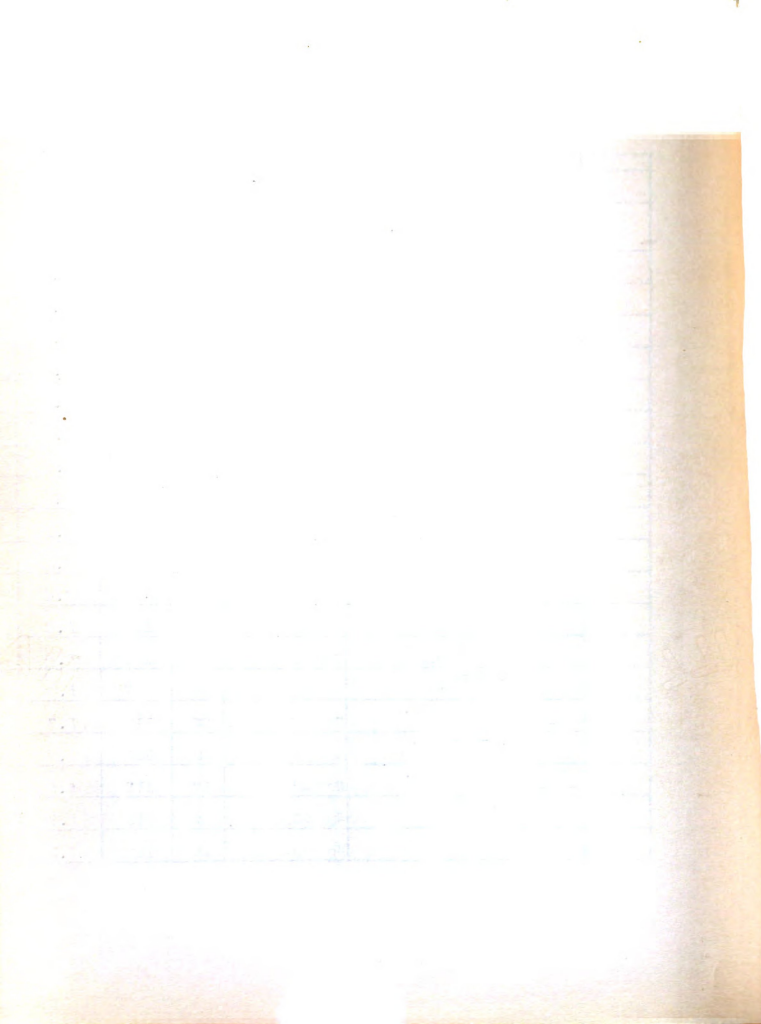
The leaf-fall was recorded by placing tags on spurs and recording the number of leaves persistent at intervals. Counts were made on the days here listed. June 1, July 16, August 7, September 19, October 1.

The extent of defoliation and the periods when it occurred are shown in Table 7 for Baldwin and in Table 8 for Red Canada.

A detailed list of materials,
method of application and degree of shading follows
in Table 6.

Table 6. Materials and Methods Used on Baldwin
and Red Canada, East Lansing, 1923.

Material	Exposure to light	Variety of apple and the por- tion of leaves sprayed.	
		BALDWIN	RED CANADA
Lime-sulphur, 2½-100	Normal	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.
Lime-sulphur, 2½-100.	Semi- shade	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.	
Lime-sulphur, 2½-100	Full shade	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.	
Bordeaux, 8-8-100	Normal	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.	Upper leaf sur- face only. Lower leaf surface only. Upper and lower. Check.
Bordeaux, 6-10-100	Normal	Upper and lower Check	Upper and lower Check
Bordeaux, 1-150	Normal	Upper and lower Check	



Experiment 7.

Abscission of Leaves on Baldwin

Apple, Belding, 1923. Records were obtained from Baldwin apple trees in 1923 at the Hall Orchards, Inc., at Belding. The Trees were mostly 20 to 22 years old and were growing in sandy loam soil with thorough cultivation during spring and early summer followed with a cover crop in late summer.

Materials and Application. A number of materials were used as follows.

1. Bordeaux, 6-18-100 (hydrated lime).
2. Lime-sulphur, $2\frac{1}{2}$ gal. in 100.
3. Lime-sulphur, $2\frac{1}{2}$ gal. in 100,
and calcium caseinate, $1\frac{1}{2}$ lb.
in 100.
4. Lime-sulphur, $2\frac{1}{2}$ gal. in 100,
and hydrated lime, 15 lbs. in
100.
5. Lime-sulphur, $2\frac{1}{2}$ gal. in 100 for
the pre-blossom applications;
90-10 sulphur-lead dust for all
post-blossom applications.

6. Sulphur-lead dust, 90% sulphur,
10% lead arsenate.
7. Check, no treatment.

Lead arsenate at the rate of 2 lbs. in 100 was used with all the spraying materials for all applications except the prepink,

The spraying materials were applied with a spray gun with the pressure usually about 275 pounds. The operator usually worked from the top of the sprayer except for the last application, when the trees were sprayed from the ground, inside and outside. The dusting materials were put on with a large power duster and usually during the late evening or early morning when there was little or no wind.

The schedule of applications consisted of the prepink, pink or cluster, petal-fall, two weeks and second brood applications according to the regular schedule of applications recommended for Michigan conditions.

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late evening or early morning when there was little
or no wind.
The schedule of applications con-
sisted of the regular, plain or diamond, pearl-
two weeks and second class applications according to
the regular schedule of applications recommended for
Michigan conditions.

Record of Abscission. The comparative amount of defoliation caused by the various materials was determined by counting the number of leaves persistent on spurs on October 3. The spurs studied were mostly on two and three year old wood and none of them had borne blossoms in 1923. The results of the counts are presented in Table 9.

**Table 9. Leaves Persistent Under Various Treatments
on Spurs of the Baldwin Apple, Belding, October 31,
1923.**

Treatment	Records from		Total No. Leaves Counted	Average per spur
	Trees	Spurs		
1. Bordeaux	3	498	1994	4.0
2. Lime-sulphur	3	553	2205	3.9
3. Lime-sulphur and calcium caseinate	3	573	1826	3.1
4. Lime-sulphur and hydrated lime	3	483	1918	3.9
5. Combination: lime-sulphur and dust	3	315	1267	4.0
6. Sulphur-lead dust	3	344	1603	4.6
7. Check	1	412	1925	4.6

Experiment 8.

Abscission of Fruit and Leaves of the Baldwin Apple, Beulah, 1923. The effect of lime-sulphur and bordeaux on the abscission of the fruit and foliage of the Baldwin apple was studied in 1923 in the Joseph Smeltzer orchard near Beulah, Benzie County. The trees were large, mature, uniform and all bloomed heavily in the spring of 1923.

Materials and Applications. Two materials, lime-sulphur and bordeaux, were used. The lime-sulphur was diluted at the rate of $2\frac{1}{2}$ gallons in 100 and the bordeaux was made according to the 6-12-100 (hydrated lime) formula. Lead arsenate paste, at the rate of 6 pounds in 100 was used with both materials.

The trees all received the pink, petal-fall, two-weeks and second brood sprays. A spray gun was used with the sprayer operating at 350 pounds pressure. The spraying was done from the ground and all trees were sprayed both inside and outside. The operator first sprayed outwards from near the center of the tree, thoroughly covering the underside of the leaves and all inner portions of the tree then worked around the outside of the tree and completed the coverage.

Record of Abscission. The effect of the two materials on the abscission of fruit and foliage was obtained by determining the numbers of apples and leaves persistent on spurs on September 18. Counts were made, for fruit records, from spurs that had blossomed in the spring of 1923 and for leaf records, from spurs that had not borne blossoms in 1923. The selection of record spurs was strictly random. Studies were made of two groups of spurs on each tree: first, those around the outside of the tree where the exposure to sunlight was good and where they probably did not receive a heavy dosage when the trees were sprayed from the inside and second, those around the lower inside portion of the tree where they were shaded considerably and where they received the full benefit of the material applied from the center of the tree. Records were obtained from four trees under each treatment and leaf and fruit records were from the same trees. The record spurs were evenly distributed around the trees. All spurs of both classes were within 4 to 7 feet from the ground. The spurs from the outside or periphery of the tree will hereafter be referred to as

"outside" spurs and those from the inner part of the tree as "inside" spurs. The data obtained in these counts are presented in Table 10. No effort was made to determine the original number of blossoms or leaves borne by each spur but on the bordeaux sprayed trees careful observation indicated that practically no leaves had fallen except the rudimentary leaves at the base of each spur. Rather heavy defoliation occurred a little later as the result of bordeaux injury which developed after the counts were made.

Table 10. Fruit and Leaves Persistent on Spurs of
the Baldwin Apple at Beulah, September 13, 1923.

Fruit	Lime-sulphur		Bordeaux	
	Inside	Outside	Inside	Outside
Total number spurs examined	459	1211	791	932
Spurs that lost all fruit (percent)	82	44	43	26
Spurs that held part of fruit (percent)	18	56	57	74
Average number apples per spur that held fruit	1.06	1.11	1.16	1.22
Number apples matured on any 100 spurs that bore blossoms	19	62	66	90
Foliage	Inside	Outside	Inside	Outside
Total number spurs examined	411	404	410	403
Total number leaves persistent	1503	1727	1937	2078
Average number leaves per spur	3.6	4.2	4.7	5.1

Experiment 9.

The Relation of the Composition of Bordeaux to the Abscission of Leaves of the Apple, East Lansing, 1924. Five year old trees of Rhode Island Greening and Duchess (Oldenburg) were used in 1924 for a series of tests to determine the effect on leaf-fall of bordeaux made with varying amounts of copper sulphate and lime and with certain impurities in the lime. Answers were sought to several definite questions. Is foliage injury increased by increases in the amount of copper sulphate used? With the amount of copper sulphate constant will extra lime reduce injury? Will injury be greater if the lime is high in Magnesia?

Methods and Materials. Each tree was divided into three portions, one of which was smaller than the others and was used as a check. The other larger portions were sprayed with bordeaux mixture, each of a different formula. The treatments were paired so that a tree of Duchess received the same treatments as a Rhode Island tree. Oiled sheets were used to prevent the spray from reaching branches that were not to be sprayed.

The materials were applied with a good bucket pump, using a fine vermorrel nozzle. The spray was always applied completely covering both upper and lower surfaces of the leaves.

The materials and the strengths at which they were used were as follows:

I. One tree each of Duchess and Rhode Island.

1. Bordeaux, 2-2-100.
2. Bordeaux, 2-4-100.
3. Check, no treatment.

II. One tree each of Duchess and Rhode Island.

1. Bordeaux, 8-8-100.
2. Bordeaux, 8-15-100.
3. Check, no treatment.

III. One tree each of Duchess and Rhode Island.

1. Bordeaux, 8-8-100.
2. Bordeaux, 8-8-100, in which magnesium oxide was substituted for 40% of the lime (calcium oxide).

3. Check, no treatment.

IV. One tree each of Duchess and Rhode Island.

1. Bordeaux 8-N-100. Lime used in just sufficient quantity to precipitate all copper

as indicated by the use of the potassium permanganate test.

2. Colloidal copper hydroxide
(Hooker) 1-5000.

3. Check, no treatment.

Chemically pure materials and rain water were used for making all the mixtures in this experiment.

Dates of Applications and Leaf-
counts. Two applications were made: 1. June 23,
and 2. July 24.

The leaf-fall records were obtained by the usual tag method. Counts were made at four periods: June 26, July 23, August 20 and October 3.

The record of leaf-fall is shown in Table 11 for Duchess and in Table 12 for Rhode Island.

Table 11. The Relat

Materials and Strengths	Recor Sour
1. Bordeaux, 2-2-100	23
2. Bordeaux, 2-4-100	25
3. Check for 1 and 2	12
4. Bordeaux, 8-8-100.	20
5. Bordeaux, 8-16-100	22
6. Check for 4 and 5.	15
7. Bordeaux, 8-8-100	21
8. Bordeaux, 8-8-100 (Line, 40% m g. oxide)	24
9. Check for 7 and 8.	14
10. Bordeaux, 8-N-100, (Ca. to neutralize Cu.)	14
11. Colloidal Cu. Hydroxide 1-5000	25
12. Check for 10 and 11.	12

Table 12.

Materials and Strengths
1. Bordeaux, 2-2-100
2. Bordeaux, 2-4-100
3. Check for 1 and 2
4. Bordeaux, 8-8-100
5. Bordeaux, 8-16-100
6. Check for 4 and 5.
7. Bordeaux, 8-8-100
8. Bordeaux, 8-8-100 (Lig 40% lig. oxide)
9. Check for 7 and 8
10. Bordeaux, 8-11-100, (Ca to neutralize Cu.)
11. Colloidal Cu. Hydroxide 1-5000.
12. Check for 10 and 11.

Experiment 10

The Effect of Various Spraying Treatments on the Abscission of the Foliage and Fruit in the Apple, Morrice, 1924. A twelve year old apple orchard at Morrice was used in 1924 for a series of tests to determine the effect of spraying materials on the abscission of leaves and fruit. The trees were in good vigor and had been in alfalfa sod for two years, the alfalfa usually has been cut and left on the ground or placed around the trees as a mulch. This work was conducted along two lines. The first, a comparative test of several materials and combinations of materials in which the application was made in the regular and usual manner, and the second, a comparison of so-called weak and strong lime-sulphur and weak and strong bordeaux in which both strengths of each material were applied at three different rates. These were termed light, moderate and heavy applications.

Materials Used and Methods of Application. In the general comparative test the following named materials were used and at the dilutions stated.

1. Lime-sulphur, $2\frac{1}{2}$ gals. in 100.
2. Lime-sulphur, $2\frac{1}{2}$ gal. in 100,
plus calcium caseinate, 1 lb.
in 100.
3. Lime-sulphur, $2\frac{1}{2}$ gal. in 100,
plus lump lime, 10 lbs. in
100.
4. Dry-mix sulphur-lime mixture,
16 lbs. sulphur, 8 lbs. lump
lime, 1 lb. calcium caseinate
and water to make 100 gals.
5. Lime-sulphur, $2\frac{1}{2}$ gals. in
100 for the pre-blossom applica-
tions and dry-mix sulphur-lime
for the post-blossom applications.
6. Colloidal sulphur (Tisdale)*, $\frac{1}{2}$
gal. in 100.
7. Colloidal sulphur (Herbert and
Herbert)**, 10 lbs. in 100.
8. Check, no treatment.

*This materials was furnished by .L..E.Tisdale,
of the Crop Protection Institute.

** This material was manufactured by Herbert &
Herbert, Inc.

Lead arsenate powder at the rate of 2 lbs. in 100 was used with all materials for all applications except the prepink. Nicotine sulphate at the rate of 1 pint in 100 was used with all materials in the petal-fall application.

These materials were all applied in the usual and regular way. The exact procedure was varied to meet conditions prevailing at any time, wind being the principal determining factor. Each tree or at least each row was completed as a unit. The spraying was all done from the ground with a spray gun with a disc aperture of 9/64 inch. The pressure was maintained quite unfairly at 300 to 310 pounds.

In the portion of the work comparing different concentration and rates of application, the materials were used as follows.

1. "Weak" lime-sulphur, $1\frac{1}{2}$ gals. in 100, and lead arsenate $1\frac{1}{2}$ lbs. in 100.
2. "Strong" lime-sulphur, 3 gals. in 100, and lead arsenate, 3 lbs. in 100.
3. "Weak" bordeaux, 2-4-100, and lead arsenate, 1 lb. in 100.
4. "Strong" bordeaux, 6-12-100, and lead arsenate 3 lbs. in 100.

The lead arsenate was used at the rates indicated for all applications except the prepink. Nicotine sulphate was used in the petal-fall application. The spraying was all done from the ground with a spray gun with a disc aperture of 1/8 inch. The pressure was maintained at 300 to 310 pounds. The general method of application was the same as described for the first part of the experiment, in that each tree or at least each row was completed as a unit but a special method was used to insure uniformity in applying each material at different rates.

Both materials at each strength were applied at three different rates, which have been termed as "light", "moderate", and "heavy" applications. Weak lime-sulphur, for example, was used on three rows; one row received the light application, another the moderate, and the third the heavy application. This was accomplished by a special method, which may be described as follows. The spraying was begun on the "heavy" row and all three were given a uniform, light application. The "light" row was sprayed no more. By the time the three rows were sprayed the materials on the first and second rows sprayed had dried and they

were immediately sprayed just as before so that the dosage was double that on the lightly sprayed row. As soon as the materials had dried from the second covering, the first row was again sprayed with the same light application. The final result was that one row received one light application, another row two light applications and the third row three light applications. This constitutes what has been arbitrarily termed "light" "moderate" and "heavy" applications. The moderately sprayed trees, then, received twice, and the heavily sprayed trees approximately three times as many gallons of diluted materials as the lightly sprayed row. It follows then that the comparative amounts of diluted materials applied to trees receiving light, moderate, and heavy applications varied as 1, 2 and 3. Strong lime-sulphur, weak bordeaux and strong bordeaux, were all applied exactly as described for the weak lime-sulphur.

Comparative Amounts of Active
Ingredients. Since the rates of application for each material varied as 1, 2 and 3 and bordeaux and lime-sulphur were each used at two concentrations it is evident that there were differences

in the amounts of actual active ingredients applied to each row and by considering together the dosage and strength of material it is possible to determine the comparative amounts used. For example, the rows sprayed with light applications of weak and strong lime-sulphur received equal quantities of diluted materials but the rows sprayed with the strong lime-sulphur received twice as much actual lime-sulphur since the diluted material was twice as strong. Other examples, could be worked out on the same basis. The comparative amounts of active ingredients under each treatment are shown in Table 13, in which is also included the comparative amounts of diluted materials. The treatment giving the smallest amount is assigned the value of 1.

Schedule and Dates of Applications.

The materials for all the work were applied according to the following schedule and at the dates indicated: 1. Prepink, May 2 and 3; 2. Pink, May 15 and 16; 3. Petal-fall, June 6 and 7; 4. Two-weeks, June 19 and 20; 5. Second brood, August 12 and 13.

Table 13. Comparative Amounts of Active Ingredients.

Materials and Strengths	Rate of Application.	Comparative amounts of	
		Diluted Materials	Active Ingredients.
Weak lime-sulphur 1½ - 100.	Light	1	1
	Moderate	2	2
	Heavy	3	3
Strong lime-sulphur, 1½ - 100. 2	Light	1	2
	Moderate	2	4
	Heavy	3	6
Weak bordeaux 2-4-100.	Light	1	1
	Moderate	2	2
	Heavy	3	3
Strong bordeaux 6-12-100.	Light	1	3
	Moderate	2	6
	Heavy	3	9

The schedule here used is the standard treatment recommended for bearing apple trees in Michigan.

Abscission of Leaves and Fruit.

Data were obtained concerning the abscission of leaves for Hubbardston and Wagener. All such records were from spurs which did not bear blossoms in the spring of 1924. A continuous record was made for Hubbardston throughout the season by means of tag records. Observations were made at the following periods.

1. June 10, 11 and 12. Tags placed and original number leaves recorded.
2. June 28 and 29. About two weeks after the two-weeks applications.
3. August 4 and 5. Just before the second brood spray and immediately after an epidemic of bordeaux leaf injury.
4. September 2 and 3. Three weeks after second brood spray.
5. September 29 and 30. Final count and tags collected. The leaf abscission records for Wagener were made for most of the spray

treatments by counting the number of leaves persistent on a large number of spurs on August 26. This record included all defoliation which had occurred during the summer.

The data for Hubbardston are presented in Tables 14 and 15, and for Wagener in Table 16.

Records pertaining to the abscission of fruit were obtained for Jonathan and Hubbardston. Individual spur records were made by placing tags on spurs and recording there on the number of buds or apples present at the time each record was made. Counts were made as follows: --

1. In pink or cluster stage.
2. Just after the first drop.
3. Soon after the June drop.

The first count indicated the original number of buds in each cluster, the second the number of apples persistent after the first drop and the third the number persistent after the June drop. The term "First drop" as used here may be defined as the abscission of fruit which occurs within ten days or two weeks after petal-fall

and the "June drop" as that usually occurring during late June or early July.

The fruit abscission records for Jonathan are presented in Tables 17 and 18 and for Hubbardston in Tables 19 and 20.

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(Continued from page 64).

Table 16. The Effect of Various Spraying Treatments on Leaf-Fall in the Wagener Apple, Morrice, 1924.

Material and Strength	Application	Tree	No. spurs examined	Total leaves persistent	Average per spur
Strong, bordeaux, 5-12-100, and lead arsenate, 3-100	Light	1	252	1040	4.1
		2	237	1052	4.4
		3	252	761	3.0
		Total	741	2854	3.8
	Moderate	1	240	848	3.5
		2	112	437	3.9
		3	174	525	3.5
		Total	526	1910	3.5
	Heavy	1	204	899	4.4
		2	521	756	3.2
		Total	435	1355	3.8

Discussion.

The individual experiments have been described and the results stated without any discussion or interpretation. The next step, then, is to bring together comparable material from the these experiments and if possible to draw some definite conclusions from the studies and comparisons. This is done in the following pages.

Specific Consideration.

THE SOUR CHERRY

The Amount of Foliar Abscission Caused by Several Spraying Materials.

Lime-sulphur. Sour cherries were sprayed with lime-sulphur in three distinct experiments in 1923 and 1924. The varieties used were Montmorency and English Morello; the locations were widely separated, one at Traverse City and the other at East Lansing; the weather conditions varied between locations and from season to season; the lime-sulphur was used at two strengths, $2\frac{1}{2}$

gals. in 100 and 3 gals. in 100; and the number of applications varied.

The foliage on trees sprayed with lime-sulphur showed, with only one exception, no definite injury which was the result of the lime-sulphur. The one exception was at Traverse City when one of the early applications caused the tips of some leaves, where the lime-sulphur had accumulated, to lose the natural green color and to assume a creamy white appearance but without any killing or breaking down of the leaf tissues and apparently with no leaf-fall which could be traced to this injury. The leaves developed their natural green color later.

The exact total amounts of leaf-fall during the summer in the various experiments is here shown.

East Lansing, 1923			<u>ACTUAL</u>	<u>PERCENT.</u>
(from Table 1)				
Montmorency (from spurs)		0.2		3.2
English Morello (from shoots)		0.9		7.5
Traverse City, 1923				
(from Table 2).				
Montmorency (from shoots)		0.9		7.5

East Lansing, 1924

(from Table 3).	<u>Actual</u>	<u>Percent</u>
Montmorency (from spurs)	0.8	15.0

Records of normal leaf-fall are difficult to get from unsprayed cherry trees because of the usual defoliation by leaf-spot, but satisfactory records were obtained with Montmorency at Traverse City in 1923, as leaf-spot injury of consequence did not develop. The leaf-fall on the unsprayed trees was 0.9 leaf from shoots (Table 1). This is what may be called normal leaf-fall and incidentally is exactly the same as that on trees sprayed with lime-sulphur. Since the amount of abscission in the other experiments is closely in line with that in the Traverse City orchard it is evident that little foliar abscission will result directly from the proper use of lime-sulphur on sour cherries under Michigan conditions.

Bordeaux. Trees of the sour cherry were sprayed with bordeaux in the same experiments, under the same conditions and with the same varieties mentioned for lime-sulphur. In addition, bordeaux was used on Early Richmond at East Lansing in 1924.

In every experiment, regardless of location, variety, weather conditions, strength of material or number of applications bordeaux caused foliage injury and defoliation. The injury which was responsible for the leaf-fall was always of the yellow-leaf type; in some instances it was light, in others severe. The statements of total leaf-fall during the summer in the various experiments follows.

East Lansing, 1923,		
(from Table 1)	Actual	Percent
Montmorency, (from spurs)	4.1	67.2
English Morello (from shoots)	9.6	79.3

Traverse City, 1923		
(from Table 2)		
Montmorency (from shoots)	1.6	1 3.0

East Lansing, 1924		
(from Tables 3 and 5).		
Montmorency (from spurs)	2.8	59.5
Early Richmond, not nitrated (from shoots)	6.3	45.5

These results indicate definitely that serious foliage injury and defoliation are very likely to follow the use of bordeaux on

sour cherries in Michigan. This statement is supported further by numerous observations in experiments not herein discussed.

Pyrox. A commercially prepared material containing bordeaux and lead arsenate sold under the brand name of Pyrox was used on Montmorency at Traverse City in 1923. The use of this material resulted in very heavy leaf-fall during mid- and late summer. The injury was the typical yellow-leaf kind caused by bordeaux. The total leaf-fall for the summer period as taken from Table 2 follows. The amount of defoliation on unsprayed trees is also shown.

	<u>Actual</u>	<u>Percent</u>
Pyrox (from shoots)	6.5	61.3
Check (from shoots)	0.9	7.7

Sulphur Dust and Copper Dust. The dusts which were used on Montmorency at Traverse City in 1923 caused practically no injury and the foliage had the same appearance and texture as normal unsprayed foliage. The amounts of leaf-fall, as compared with that on untreated trees was as follows (from Table 2).

	<u>Actual</u>	<u>Percent</u>
Copper dust (from shoots)	0.9	8.5
Sulphur dust (from shoots)	0.7	6.4
Check (from shoots)	0.9	7.7

Alternation of Materials -- Lime-sulphur and Bordeaux. At Traverse City and East Lansing in 1923 changes of materials were made during the season in some instances. Bordeaux was substituted for lime-sulphur in one plot at Traverse City in the petal-fall application and in another in the four-weeks application. At East Lansing bordeaux was substituted for lime-sulphur in the two-weeks application. Montmorency was the variety at both places. In each instance the change of material resulted in foliage injury and an epidemic of yellow leaves in one week to ten days later. The comparative amounts of leaf-fall follow.

	<u>Actual</u>	<u>Percent</u>
Traverse City (from Table 2)		
Lime-sulphur, applic.		
1, 2 & 4; bordeaux, applic. 3.	1.6	13.0
Bordeaux, applic. 1; Lime-sulphur, applic. 2, 3, & 4.	1.5	14.0
East Lansing, (from Table 1).		
Lime-sulphur, applic. 1 and 3; bordeaux, applic. 2.	1.7	32.6

In another instance with English Morello at East Lansing in 1923, a tree was accidentally sprayed with both lime-sulphur and bordeaux in the same afternoon. Almost complete defoliation followed as well as injury to the bark and young cherries. Many instances were reported from various parts of the state during that season where severe foliage injury followed a change from one material to another. The injury apparently was not correlated with a change in one way, as from lime-sulphur to bordeaux or vice versa as it was known to have occurred with both. It was very evident that there was some reaction between certain constituents of the two materials to form a soluble and toxic compound.

Nutritive Condition of the Tree in
Relation to Bordeaux Injury.

Some attention was given to the question of tree vigor in the sour cherry and its relation to the development of bordeaux injury. In other words, is a cherry tree in one plane of nutrition more likely to suffer from bordeaux injury than trees in other conditions?

Trees in low vigor have been very generally observed as being more susceptible to injury by leaf-spot and it seemed desirable to determine if the same condition is true with regard to bordeaux injury.

Studies were made in two orchards, one at Traverse City in 1923 (Experiment 4) and one at East Lansing in 1924 (Experiment 5). The condition of the trees at Traverse City may be described as follows. One group had been badly defoliated in 1922 by leaf-spot and were in a weak condition in the spring of 1923; the others had been only slightly defoliated and were in normal condition. Analyses of spurs and shoots collected in early spring from other trees in similar condition showed the two groups to have had comparable amounts of total nitrogen but the reserve of starch and sugars was very low in the trees defoliated in 1923*. This was the condition at the beginning of the growing season but just what it was during the summer when defoliation occurred is not known. At

*Mich. Exp. Sta. Sp. Bul. 147. p. 7.

East Lansing in 1923 the trees were in a uniformly low condition of vigor to begin with but the nutritive state of one lot was changed by a heavy application of nitrate of soda in the early spring so that vegetative growth was accelerated during the summer. In one instance then, the tree had been on an equal plane to begin with but one lot had the carbohydrate reserves lowered as a result of defoliation. In the other, the trees were in an equally low plane of vigor but one group was changed by the use of nitrate of soda. There were undoubtedly differences in the nutritive condition of the two groups in each experiment, but what this difference was is not known.

All trees in each experiment, as stated in the description of the experiments, were sprayed uniformly. The results, taken from Tables 4 and 5, may be summarized as follows.

	<u>Actual</u>	<u>Percent.</u>
Montmorency at Traverse City		
Trees in low carbohydrates in spring of 1923	1.4	14.7
Normal trees	1.0	10.6
Early Richmond, East Lansing		
Nitrated trees	10.1	67.7
Normal trees	6.3	47.0

The evidence is not extensive or conclusive enough to allow the drawing of any definite conclusions but it indicates that the nutritive condition of the tree has some relation to its susceptibility or resistance to bordeaux injury.

THE APPLE

The Amount of Foliar Abscission Caused By Various Materials.

Lime-sulphur. Two general types of injury on apples resulting from the use of lime-sulphur and acid lead arsenate have been described in preceding paragraphs and both have occurred during the course of the work herein reported. Equally complete records, however, were not obtained for both.

Yellow-leaf Injury. Lime-sulphur and lead arsenate were used at Belding, Experiment in 1923 in comparison with the same materials to which had been added certain materials intended to retard the reaction between the lime-sulphur and lead arsenate and consequently to reduce the amount

of injury. Excess lime was used in one instance and calcium caseinate in another. Sulphur dust was also used in comparison with the other materials. Very little injury developed at any time except after the last application when the trees were sprayed from the inside as well as outside. About two days after this application yellow leaves were in evidence in many plots. The comparative amounts of defoliation were determined by counting the leaves persistent on spurs early in October. The original number of leaves present on the spurs was not determined but the check tree may be assumed as being normal as scab infestation on the foliage was not severe and had caused little or no defoliation.

A summary of the material presented in Table 9 follows, showing the number of leaves persistent on spurs at the first of October.

Check	4.6
Sulphur-lead dust	4.6
Combination schedule of lime-sulphur and sulphur dust	4.0
Lime-sulphur plus lime	3.9
Lime-sulphur	3.9
Lime-sulphur plus calcium caseinate	3.1

The loss of foliage was not severe with most of the materials but the results give some comparative effects.

Another and extensive experiment was started at Morrice where it was planned to obtain more definite data but the work in that particular orchard was given up because of loss of the crop from frost injury. General observations were made in another orchard on the same farm where several combinations were used. They indicated that excess lime with lime-sulphur and lead arsenate did not appreciably reduce the amount of yellow-leaf injury. The use of calcium caseinate, however, did seem to lessen this injury. The observations there were made on Rhode Island and Stark. The trees were sprayed at every application from the ground, inside and outside, and yellow leaves were present in numbers following all post-blossom applications. The total amount of leaf-fall was greater than at Belding.

At Beulah in 1923 records were obtained from Baldwin to determine the comparative amount of injury caused by lime-sulphur and bordeaux. The injury on lime-sulphur sprayed trees was of the yellow-leaf type and developed mostly after the two-weeks application. In early

September outside spurs on lime-sulphur trees had an average of 4.2 leaves per spur as compared with 5.1 on bordeaux trees. The number present on the bordeaux trees was probably about normal for that time of year and under conditions that had prevailed in that orchard.

The results obtained from the young trees at East Lansing in 1923 were rather inconclusive but indicate that lime-sulphur alone does not cause much injury under weather conditions that prevailed that season. The data presented in Table 7 show that Baldwin trees sprayed with lime-sulphur (complete application and normal exposure) lost no more leaves than unsprayed trees with normal exposure. Red Canada (Table 8) with a complete application of lime-sulphur lost 2.3 leaves per spur in comparison with 1.0 for the check.

Brown-leaf or Scald Type of Injury.

The injury that developed on apples in 1924 was almost entirely of the type described as brown-leaf or scald, as the leaves did not turn yellow before they were abscised but became brown as if scalded. When the injury was severe the leaf fall,

when less severe or only slight the leaf persisted but frequently a portion of the leaf broke off so that many persistent leaves were not entire. The extent of this type of injury was studied in the orchard at Morrice (Exp. 10) with Hubbardston and Wagener. In this experiment, the work was divided; first, a general comparison of several materials and combinations and second, a comparison of different strengths of lime-sulphur and bordeaux applied at various rates. The results for the first will be discussed here, the second will be considered later.

The materials used in the first part of the work may be separated into three groups; --

1. Lime-sulphur.
2. Lime-sulphur to which some material was added to lessen injury of certain types.
3. Materials with sulphur as the active agent but present as free sulphur.

In the first two groups the sulphur

was present in what may be termed an "active" form as it is in solution in the form of polysulphides and thiosulphate. In the third group, the sulphur was present in a relatively "inert" form, as free sulphur and colloidal sulphur.

The total defoliation resulting from injury of the brown-leaf or scald type occurring with each of the materials when used on Hubbardston was as follows. The data are taken from Table 14.

Group 1.

	<u>Actual</u>	<u>Percent</u>
Lime-sulphur	3.4	43.0

Group 2.

Lime-sulphur with excess lime	3.7	48.6
Lime-sulphur and calcium caseinate	4.4	55.6

Group 3.

Dry-mix sulphur-lime	2.4	30.7
Dry-mix and lime-sulphur (combination schedule)	2.0	25.3
Colloidal sulphur (Tisdale)	1.9	24.3
Colloidal sulphur (Herbert & Herbert)	2.5	32.0
Check, no treatment	1.8	23.0

A study of these results shows that the so-called inert materials caused much less leaf-fall than the active materials. The active materials all caused much more leaf-fall than the inert materials but in the group where excess lime and calcium caseinate were added the injury was noticeably greater than where lime-sulphur was used alone. Lead arsenate was used with all materials but it seems safe to disregard it here as there is no reason to believe that it was involved in the injury that developed.

Records were also obtained for Wagener for part of the materials used in the general comparative tests. A summary of these data, taken from Table 16, follows. The records here show the number of leaves persistent on spurs at the end of the summer and in comparing the results from the several materials it is necessary to assume that the original number of leaves per spur averaged about the same for all treatments.

	Group 1.	Leaves persistent
Lime-sulphur		2.6
	Group 2.	
Lime-sulphur and calcium caseinate		1.4
	Group 3.	
Dry-mix sulphur-lime		2.6

The results here are comparable with those on Hubbardston except that there is no difference between the final effect of the inert material (dry-mix) and lime-sulphur alone. There is no evidence at hand to explain this difference but it may be suggested that some leaf-fall may have occurred where dry-mix was used as a result of scab infection on the foliage. This was rather severe in this plot.

In general, the results indicate that under conditions favorable for the development of brown -leaf injury the so-called inert materials, as dry-mix sulphur-lime and colloidal sulphur will cause relatively little defoliation; That lime-sulphur without the addition of special materials will cause considerably more and enough to be considered serious; and that the use of lime-

sulphur to which has been added excess lime or calcium caseinate will result in severe leaf-fall.

Comparative Amount of Leaf-fall

Following Yellow- and Brown-leaf Types of Injury.

A comparison of the amounts of leaf-fall occurring in 1923 when conditions were favorable for the yellow-leaf type and in 1924 when they were favorable for the brown-leaf type, shows in general that the latter may be more severe when certain materials are used. Comparing the amounts of the two kinds of injury caused by any one of the three groups of materials just discussed shows some interesting facts. The inert materials (dry-mix, colloidal sulphur and sulphur-lead dust) may be expected to cause relatively little injury of either type. Lime-sulphur and lead arsenate will cause both but with strength of material and application uniform the brown-leaf injury will likely be more severe than the yellow-leaf. The addition of excess lime to the lime-sulphur and lead arsenate combinations resulted in a slight reduction in leaf-fall when yellow-leaf injury

prevailed but increased leaf-fall when conditions were favorable for the development of the brown-leaf injury. The relation of calcium caseinate to yellow-leaf injury is rather doubtful but brown-leaf injury was definitely increased by adding it to the lime-sulphur.

The Relation of Weather Conditions to the Development of Brown-leaf Injury. The type of foliage injury developing on apples in 1924 was, as previously stated, different from the usual injury following the use of the lime-sulphur and lead arsenate spray, that is, the yellow-leaf type which is probably the result of soluble arsenic. This brown-leaf injury was observed generally in many parts of Michigan in 1924, it was seen in southern Ohio on varieties typical of that district and it was reported as being very severe in the apple growing districts of Pennsylvania. The fact that it occurred in widely separated districts, on many varieties and with many growers using various methods of application and brands of spraying materials automatically eliminates the possibility that it may have been the result of faulty application or improperly made spraying materials. The nature of the

injury indicated that it was in some way connected with tender foliage which was not resistant to the caustic action of lime-sulphur and in this connection it has been stated in the introductory paragraphs that the nature of the season has a very definite relation to the type of leaf, particularly affecting the development of the cuticle.

On the basis of these observations and facts, it seemed desirable to study the weather conditions that prevailed in 1924 in districts where this brown-leaf injury was known to have been rather serious. The weather of 1924 was compared with that of 1923 since none of the brown leaf injury was observed during that year. Records are presented in Table 21 for the months of May and June for certain conditions of the weather at East Lansing, Michigan, Columbus, Ohio, and Harrisburg, Pennsylvania. These records were obtained from the stations of the United States Weather Bureau at each place. The study was confined to May and June as it is during these months that most of the leaf-growth on spurs takes place.

A study of the data in Table 21

shows consistent differences for both months at all stations. The mean temperature was consistently lower in 1924, the total precipitation and the number of days with rainfall were greater for 1924, the percentage of possible hours of sunshine was consistently lower and the mean humidity was higher in 1924 than in 1923. These conditions were such that, with other things equal, leaves grown in 1924 would be more tender than those of 1923 and consequently would be more susceptible to the caustic action of freshly applied lime-sulphur. This statement has no reference to the brown-leaf injury following applications of lime-sulphur when the temperature is high.

Bordeaux. There is only one type of injury resulting from the use of bordeaux which has been observed as responsible for leaf-fall in the apple in the course of the experiments herein discussed. Unless otherwise specified any reference will be to the yellow-leaf injury.

Bordeaux was used in several experiments in various orchards. At Belding in 1923 (Exp. 7) records were obtained from Baldwin. In that ~~one~~ orchard the average number of leaves persistent on spurs on October 3 on bordeaux sprayed trees was 4.0 as compared with 4.6 for unsprayed trees. (Table 9) In this experiment, then, the leaf-fall resulting from bordeaux injury was insignificant. At Beulah in 1923 (Exp. 8) and on Baldwin again, bordeaux had caused no apparent injury as late as September 13 but considerable injury and defoliation did occur a little later. At East Lansing, 1923, (Exp. 6) the use of 8-8-100 bordeaux (with complete application) resulted in a total leaf-fall on Baldwin (Table 7) of 5.0 leaves per spur as compared with 1.6 leaves for checks. On Red Canada trees (Table 8) in the

same experiment a like treatment resulted in the loss of 6.6 leaves per spur as compared with 1.3 for the check. In another experiment at East Lansing in 1924 (Exp. 9) the use of 8-8-100 bordeaux on Duchess (Table 11, Items 4 and 7) caused nearly complete defoliation in comparison with a loss of one-third to about one-half the leaves on checks (Items 6 and 9). The leaf-fall in the last period (ending October 3) with this variety was heavy on sprayed and unsprayed alike. With Rhode Island, in this experiment, (Table 12, Items 4 and 7) the 8-8-100 bordeaux caused leaf-fall to the extent of 6.9 and 7.3 leaves per spur as compared to 2.4 and 3.2 for the checks (Items 6 and 9). At Morrice in 1924 (Exp. 10) a moderate application of 6-12-100 bordeaux caused injury and defoliation to the amount of 2.1 leaves per spur as compared with 1.8 for the check. Considerable defoliation was caused, however, on the check by a heavy infestation of scab on the foliage so that the leaf-fall on the check must be considered greater than normal. Wagener in the same orchard (Table 16) with like treatment

had 3.6 leaves persistent on spurs at the end of the summer as compared to 4.6 and 4.7 under other treatments where there was little injury.

A study of these results as whole show that the use of bordeaux on apples may frequently result in some abscission of leaves but the injury frequently occurs so late in the season or to such a small extent that the effect on the tree may be relatively less serious than when heavy defoliation takes place early in the season.

The Relation of Strength Material and Rate of Application to the Development of Foliage Injury in the Apple. The second part of Experiment 10 consisted of a comparison of two strengths each of lime-sulphur and bordeaux, and each applied at three different rates. The results of this work are summarized and discussed in the following paragraphs and in this connection there are several angles to be considered: -- the strength of the material, the rate of application, and the relative amounts of actual active materials present. Lime-sulphur and bordeaux will each be considered by itself and not compared, one with the other.

Lime-sulphur. Two strengths of lime-sulphur were used, $1\frac{1}{2}$ - 100, and 3 - 100. These have been termed "weak" and "strong". Each strength was applied at three rates which have for convenience and in a relative way been called, "light", "moderate", and "heavy" applications. Records of leaf-fall were obtained in detail for Hubbardston and in less detail for Wagener.

A comparison of weak lime-sulphur and strong lime-sulphur, with equal dosage shows definitely that the strong caused great injury and defoliation. This is shown for Hubbardston (from Table 15) in the following tabulation in which is stated the total leaf-fall under each treatment.

Dosage	Weak	Strong
Light	1.8 (22%)	3.6 (43.9%)
Moderate	2.8 (35%)	5.1 (63.0%)
Heavy	3.8 (46%)	5.6 (76.7%)

With Wagener the results (from

Table 16) are stated in terms of the number of leaves persistent on spurs at the end of summer.

<u>Dosage</u>	<u>Weak</u>	<u>Strong</u>
Light	4.6	2.1
Moderate	3.2	1.9
Heavy	2.6	0.8

A comparison of results of different rates of application but with the strength of material the same shows conclusively that an increase in dosage results in a greater amount of injury. This is shown clearly for both Hubbardston and Wagener in the tabulations just preceding this paragraph.

The relation of the relative amounts of actual lime-sulphur to the degree of leaf-fall is shown for Hubbardston in Figure 1. The amount of actual lime-sulphur applied to any tree was of course determined by two other factors: strength of material and rate of application. The

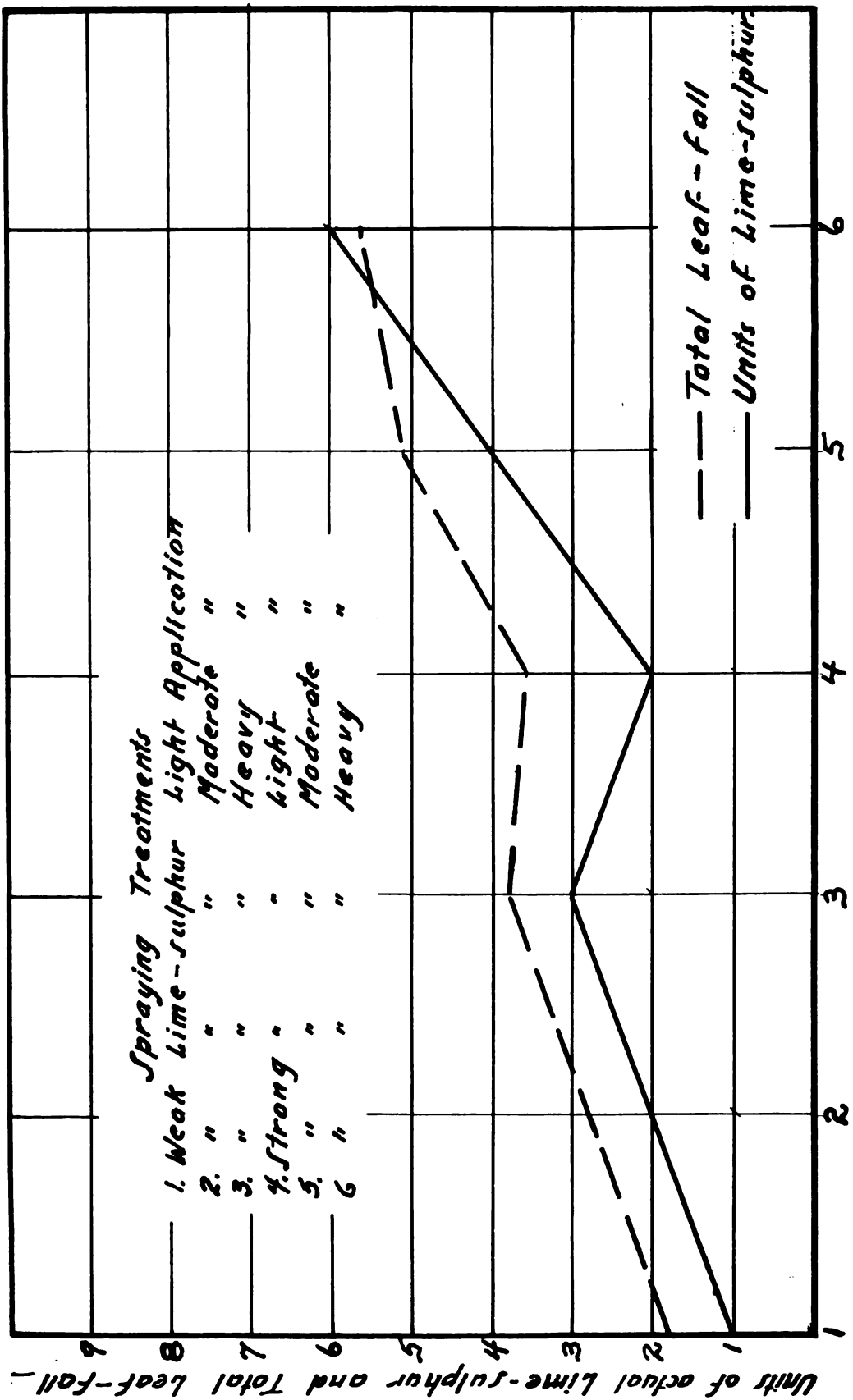
graph in Figure 1 shows that leaf-fall is very closely proportional to the number of units of lime-sulphur used.

It should be made clear at this point that the results stated in this section of the discussion apply only to the brown-leaf type of lime-sulphur injury and not to the yellow-leaf kind.

Bordeaux. Comparisons similar to these made for lime-sulphur may also be made with bordeaux. The weak bordeaux was made by the 2-4-100 formula and the strong by the 6-12-100 formula and both were applied at three rates; -- light, moderate, and heavy applications.

The amount of defoliation on bordeaux sprayed trees, regardless of strength of materials or dosage, was rather light and was the result of epidemic of yellow leaves that occurred in late July and early August. The results for Hubbardston (from Table 15) and for Wagener (from Table 16) are presented in the following tabulations.

The total leaf-fall from spurs for Hubbardston is first.



Spraying Treatment
 Figure 1. The Relation Between the Amount of Actual Lime-sulphur and Total Leaf-fall from Spurs of the Hubbardston Apple, Morrice, 1924.

Dosage	Weak	Strong
Light	1.1 (14.4%)	2.1 (26.5%)
Moderate	1.6 (21.1%)	2.1 (27.1%)
Heavy	1.8 (23.0%)	1.5 (19.7%)

The number of leaves persistent on spurs of Wagener at the end of summer is shown in the second.

Dosage	Weak	Strong
Light	4.7	3.8
Moderate	4.4	3.6
Heavy	4.0	3.8

Studied on the basis of strength of material it is found that with equal dosage the strong bordeaux usually caused slightly greater leaf-fall.

From the point of view of rate of application, each increase in dosage of the weak bordeaux caused slightly more foliage injury

with both varieties but the results were not so consistent with the strong.

The relation of the comparative number of units of copper in bordeaux to the amount of leaf-fall is not very definite as shown in Figure 2 and in fact the differences are so small that it is evidently unsafe to draw any conclusions from the results of this work with bordeaux, under the conditions that prevailed in that orchard during the season when the work was done. Under other conditions, more favorable for bordeaux injury, the results might have been entirely different.

The comparative amounts of defoliation under the various treatments is also shown for both Hubbardston and Wagener in a series of photographs taken on September 23. This is shown in the photographs in two ways: -- first, by general views of the trees to show the density of the foliage mass, and second, by close-up views of a few spurs to show the comparative numbers of leaves present. The photographs of the trees and spurs of Hubbardston are shown in Figures 3 and 4 and for Wagener in Figures 5 and 6.

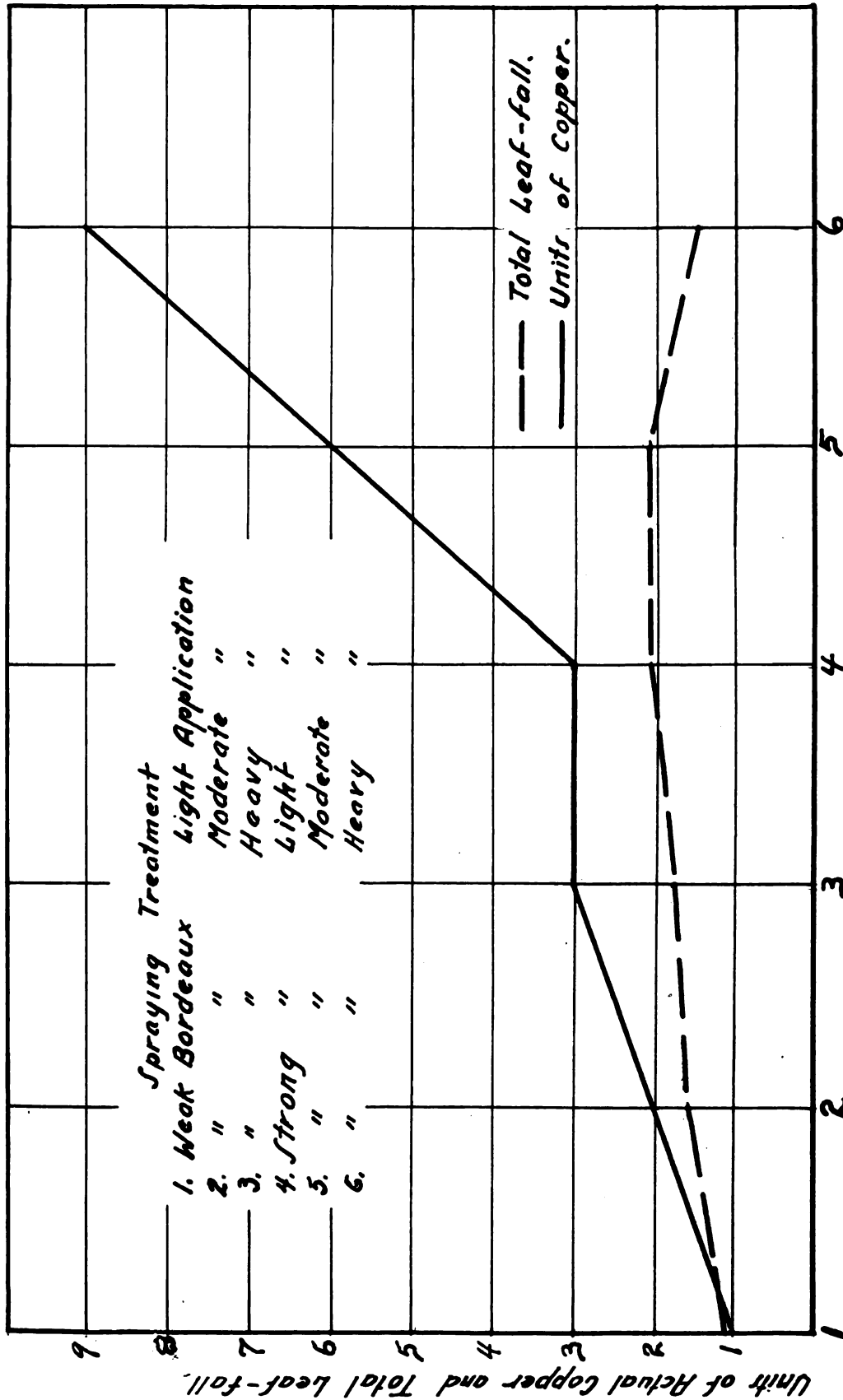


Figure 2. The Relation Between the Amount of Actual Copper and Total Leaf-fall from Spurs of the Hubbardston Apple, Morrisc, 1924.



Tree Line-sulphur, Light application.



Tree Line-sulphur, Moderate application.





Weak Bordeaux, light application.



Weak Bordeaux, moderate application







Weak Lime-sulphur, Light application.

Weak Lime-sulphur, Moderate application.





W. B. Bordeaux, Light Application.



W. B. Bordeaux, Moderate Application.



The question of strength of materials and rate of application cannot be decided entirely on the basis of foliage injury. The combination that is best to use is the one that will give satisfactory pest control with a minimum of foliage injury. Results obtained in connection with these experiments, but not discussed in this paper, show that with lime-sulphur, a medium concentration and moderate rate of application gave the most satisfactory results, considering both pest control and foliage injury. With bordeaux it was found that the strength can be reduced considerably below that generally used and still get satisfactory scab control. The results, however, with regard to foliage injury as stated in foregoing paragraphs were not definite but so much russetting of the fruit occurred that the use of ordinary bordeaux does not seem advisable.

The Effect of Spraying Materials on the
Abscission of the Fruit in the
Apple.

Records were obtained in two experiments, one in 1923 and the other in 1924 to

determine if spraying materials affect the abscission of young apples. This work was done in two orchards and with three varieties.

The work in 1923 was with mature Baldwin trees at Beulah. One lot of trees was sprayed with lime-sulphur and the other with bordeaux. The details of methods are discussed in Experiment 8. The results (from Table 10) which are summarized here show a definite difference between the effects of the two materials. The comparison here is made in terms of the number of apples matured on any 100 spurs that bore blossoms in the spring.

Material	Inside Spurs	Outside Spurs
Lime-sulphur	19	62
Bordeaux	66	90

The percentage of spurs on bordeaux trees, both inside and outside, that retained fruit was much higher than on lime-sulphur trees and the average number of apples on these spurs was higher for the bordeaux trees.

The work in 1924 was done at Morrice in connection with Experiment 10. Records were obtained from Jonathan and Hubbardston.

The data for both varieties from the general comparative test will be considered first. The results for Jonathan (from Table 17) is condensed and presented in the following tabulation. The figures given are for the final count made after the June drop.

Material	Spurs Retaining fruit	Apples per Spur	Apples on 100 Spurs
Lime-sulphur	61%	1.2	73
Lime-sulphur plus lime	90%	1.5	135
Lime-sulphur plus calcium caseinate	53%	1.2	63
Dry-mix sulphur- lime.	81%	1.4	115
Dry-mix and lime- sulphur -- bomb. schedule.	85%	1.7	136
Colloidal sulphur (Tisdale)	48%	1.4	67
Colloidal sulphur (Herbert & Herbert).	79%	1.6	126

This data shows that lime-sulphur

and lime-sulphur plus calcium caseinate reduced the final set of fruit much below lime-sulphur plus lime, dry-mix for all or part of the applications and colloidal sulphur (Herbert and Herbert). The results of the other colloidal sulphur was about the same as the first two mentioned. Reference to Table 17 shows a peculiar effect where lime-sulphur plus calcium caseinate was used. The first drop was relatively light but the June drop was very heavy so that the final set was less than with lime-sulphur alone. The fruit set on the check trees is given in Table 17 but no mention has been made of this in the discussion because of severe injury to the young fruits by scab.

The results for Hubbardston (from Table 19) for the general comparative tests are condensed and presented in the following tabulation.

Material	Spurs Retaining Fruit	Apples per Spur	Apples on 100 Spurs
Lime-sulphur	35%	1.2	42
Lime-sulphur plus lime.	40%	1.0	40
Lime-sulphur plus calcium caseinate	43%	1.0	43
Dry-mix sulphur lime.	30%	1.0	30
Dry-mix and lime-sul- phur, com- bination schedule	49%	1.1	53
Colloidal sul- phur (Tis- dale)	50%	1.1	55
Colloidal sulphur (Herbert & Herbert)	50%	1.2	60

The final fruit set with Hubbards-
ton with all treatments was lower than the poorest
on Jonathan and the differences are so small that
conclusions would seem unreliable.

Fruit-set records were also obtained
for both varieties from the comparison of weak
and strong materials applied at various rates.

The tidal limit was with respect to all trees was lower than the point then and the difference was so small that it was not noticeable. Fruit was also obtained from the vegetation of the beach and material applied at various points.

The results with Jonathan from Table 18 may be stated as follows.

Material			Spurs Retaining Fruit	Apples per Spur	Apples on 100 Spurs
Weak	Light	Applic.	51%	1.3	66
lime-	Moderate	"	29%	1.0	29
sulphur	Heavy	"	36%	1.4	50
Strong	Light	"	27%	1.0	27
lime-	Moderate	"	33%	1.1	36
sulphur	Heavy	"	13%	1.0	13
Weak	Light	"	97%	1.5	145
bordeaux	Moderate	"	62%	1.4	86
	Heavy	"	50%	1.0	50
	Light	"	89%	1.7	151
Strong	Moderate	"	72%	1.1	79
Bordeaux	Heavy	"	78%	1.6	124

No effort will be made to correlate strength of materials and rates of application with fruit-set and the results are very irregular but a comparison of the lime-sulphur group as a whole with the bordeaux group shows a distinct difference in results in favor of bordeaux.

The results with Hubbardston (from Table 18) follow.

Material			Spurs Retaining Fruit	Apples Per Spur	Apples on 100 Spurs
Weak	Light applic.	"	51%	1.3	66
lime-	Moderate	"	29%	1.0	29
sulphur	Heavy	"	36%	1.4	50
Strong	Light	"	27%	1.0	27
lime-	Moderate	"	33%	1.1	36
sulphur	Heavy	"	13%	1.0	13
Weak	Light	"	97	1.5	145
bordeaux	Moderate	"	62	1.4	86
	Heavy	"	50	1.0	50
Strong	Light	"	89	1.7	151
bordeaux	Moderate	"	72	1.1	79
	Heavy	"	78	1.6	124

The results with Hubbardston are again very irregular but a comparison of the two groups as a whole indicates that a heavier set may be expected on trees sprayed with bordeaux than with lime-sulphur.

The results with regard to the relation of spraying materials to the abscission of apples are not such that definite conclusions are justified but there is very good evidence that lime-sulphur will, with some varieties at least, cause a heavier abscission of fruits than occurs where bordeaux or some of the less active forms of sulphur are used.

Some General Considerations with Regard
to Foliage Injury.

The Relation of Time of Application
to Time Development of Foliage Injury. A study of the data presented in the several tables, in which a comparison is made of the dates of application and the periods when leaf-fall occurred, brings out some interesting facts which may in a general way be stated as follows. Brown-leaf and yellow-leaf injuries following the use of lime-sulphur and lead arsenate both develop soon after an application but may not develop after all applications. Bordeaux injury of the yellow-leaf kind may develop soon after an application but may also be delayed indefinitely.

These facts are illustrated in four graphs presented in Figures 7, 8 and 9. In Figure 7 are presented the results with Montmorency cherry at East Lansing in 1923 (Experiment 1 and Table 1). The graph shows clearly that lime-sulphur caused no injury of consequence and that bordeaux caused practically no injury until

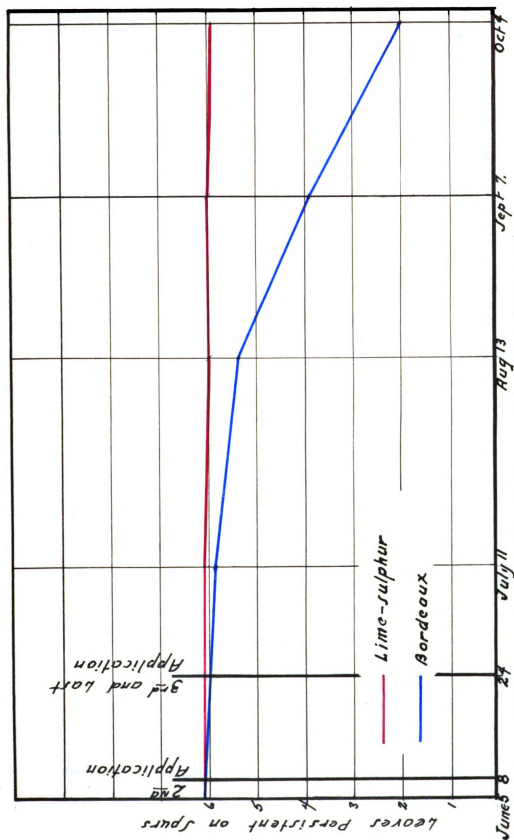


Figure 7. Time of Application and Leaf-counts. Time of Development of Foliole Injury on Montmorency Cherries, East Lansing 1923.

long after the last application which was made on June 24. The first injury of consequence occurred in early September and continued through the month. In Figure 8 are presented in graphic form the results with Montmorency at East Lansing in 1924 (Experiment 3 and Table 3). Lime-sulphur again caused relatively little injury and bordeaux very little until late in the last record period.

In Figure 9 are shown the results obtained at Morrice in 1924 with the Hubbardston apple (Experiment 10 and Tables 14 and 15). The applications earlier than the two-weeks are not shown as no injury was observed previous to that time and careful observations indicated that the leaf-fall on bordeaux-sprayed trees was probably only normal as no definite injury resulting from bordeaux was seen until much later. Definite injury did develop, however, in the lime-sulphur plot and the total leaf-fall for the first period is an expression of the normal fall plus that resulting from lime-sulphur injury. No further leaf-fall occurred on the lime-sulphur sprayed trees until immediately after the second-brood spray when severe injury developed, but there was no recurrence of injury or defoliation after that period. The bordeaux trees, on the other hand,

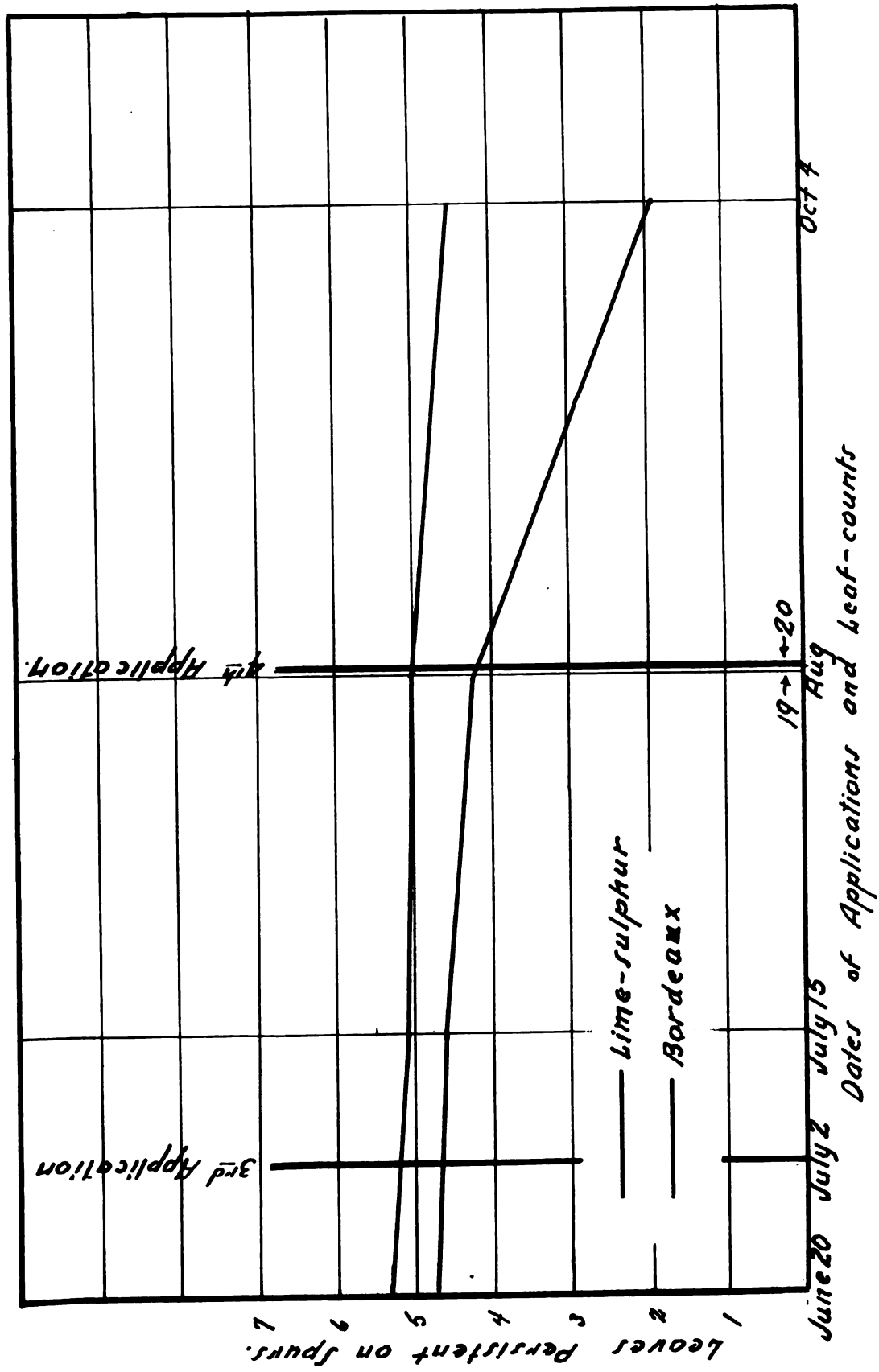


Figure 8 Time of Application in Relation to the Development of Injury on Montmorency cherries, East Lansing 1924

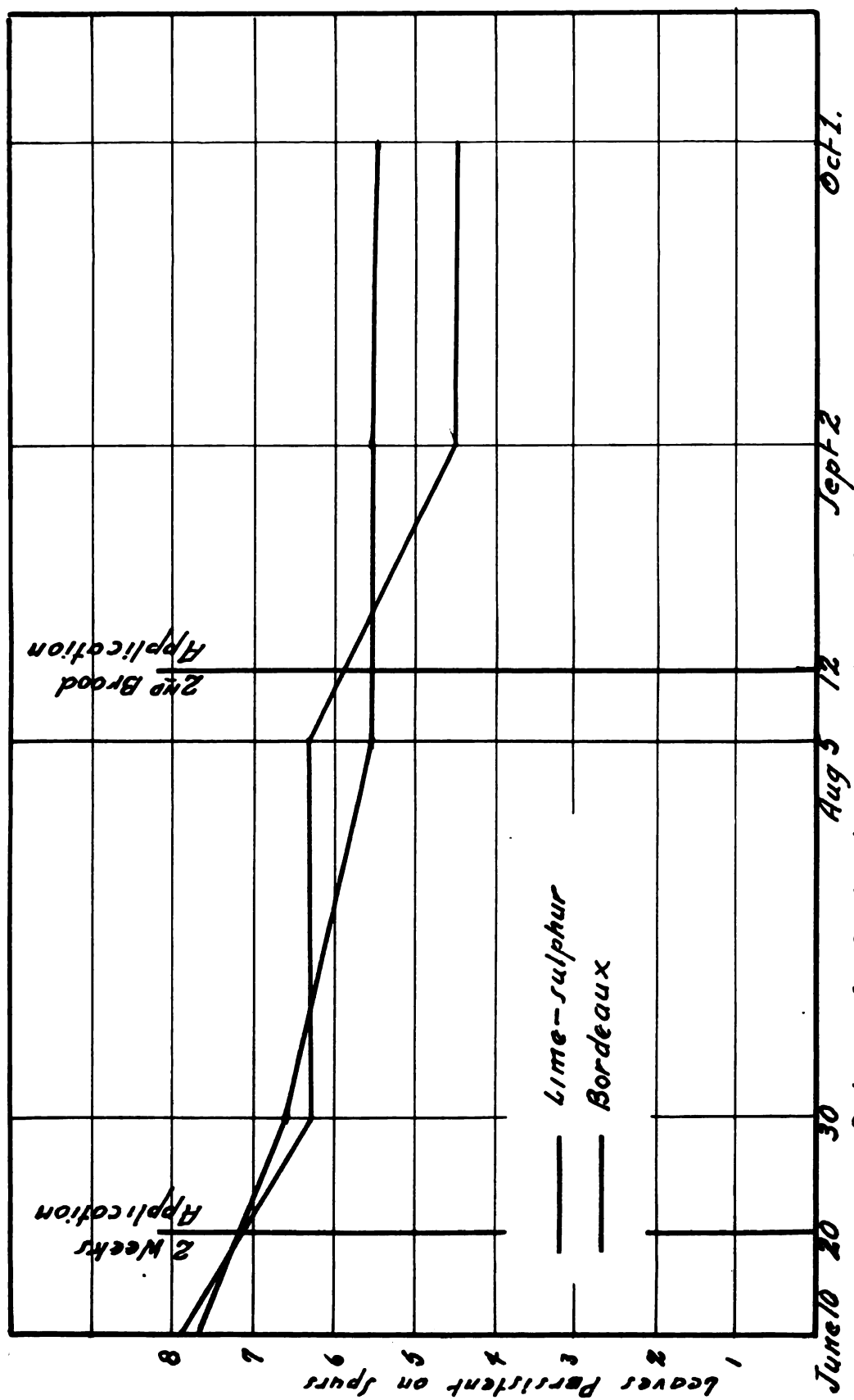


Figure 9. Time of Application in Relation to the Time of Development of Foliage Injury in the Hubbardston Apple, Morrice, 1924.

lost some leaves as a result of bordeaux injury which developed shortly before the second-brood application. No leaf-fall occurred on bordeaux sprayed trees after that application.

In other experiments as at Beulah in 1923 (Experiment 8) the only injury observed in bordeaux sprayed trees developed in late September while the injury on lime-sulphur sprayed trees occurred immediately after the two-weeks and second-brood sprays. In work at Belding in 1922, which has not been discussed in this paper, bordeaux injury was not seen until late September and early October.

The conclusion to be drawn, then, from these studies is that injury of either type on trees sprayed with lime-sulphur and lead arsenate may be expected to develop shortly after an application and that there will be no recurrence until after another application but with bordeaux the injury and accompanying leaf-fall may not and usually does not occur until a considerable time after any particular application. Bordeaux injury may also continue in a gradual way or recur in epidemic form with another application.

Just what the factors are that may

be responsible for these conditions are not fully understood but the discussion in the paragraphs that follow immediately may throw some light on the subject.

The Relation of Weather Conditions to
the Development of Foliage Injury.

Definite studies have not been made to determine just what conditions are favorable for the development of the yellow-leaf type of injury following the use of the lime-sulphur and lead arsenate spray but since this injury was uncommon in 1924 it may be assumed that the state of weather and plant growth that prevailed then was not favorable for such injury but it is not possible to state just what really does favor its development. Certain conditions of the weather for a portion of the summer of 1924 have been presented in the foregoing pages. The conditions that apparently favor the development of brown-leaf injury have already been fully discussed and will not be repeated here.

In the course of these investigations

and in connection with many other experiments, bordeaux injury to the foliage of the apple and cherry has been observed in many degrees. It has not been possible to correlate every epidemic with some meteorological condition and in fact, all the injury seen has not developed in epidemic form but in a gradual way. There has been one definite observation, however, which is that nearly every severe and definite epidemic of yellow leaves resulting from the use of bordeaux has been preceded by a period of foggy weather or light rains with relatively high temperature and further these epidemics have occurred in seasons or in the portion of a season when rainfall was relatively light.

A number of instances may be cited. In 1919 at Grand Rapids cherries and plums were sprayed with bordeaux. The summer was extremely dry but rather heavy defoliation occurred following light showers in late afternoon and evening so that the foliage remained wet, probably, all night. At Traverse City with Montmorency cherries

foggy weather with rather high temperature but no rain of consequence was followed by an epidemic of yellow-leaf injury. At East Lansing in 1923 (Experiment 1) Montmorency cherries were sprayed with bordeaux. On August 30 a heavy fog occurred with temperature about normal. The leaf-count made on September 7 showed a leaf-fall of 1.4 leaves per spur and the full effect of the epidemic had not been felt at that date. No precipitation of consequence had occurred during August. In 1924 at East Lansing heavy fogs occurred on September 17, 18, 20 and 21. For the last two dates the fog began in the evening of the 20th and continued until nearly the middle of the forenoon of the 21st. This fog was very heavy and the temperature was high. The mean lowest temperature for the month was 46.5 degrees F. while the minimum temperature for the morning of September 21 was 58 degrees F. This was followed by an epidemic of yellow leaves on both apples and cherries. At Morrice in 1924 with apples the only time that defoliation on bordeaux sprayed trees occurred was in early August. About ten days earlier a light rain had fallen in the evening, so that the trees remained

wet during the night.

All the defoliation caused by bordeaux injury cannot be accounted for in this way but, as previously stated, all the severe epidemics of yellow leaves followed the conditions described and the evidence seems to justify the conclusion that yellow bordeaux injury on apples and cherries in Michigan is most likely to develop during periods when fogs or light rains prevail and when the temperature is relatively high.

Strength and Composition of Bordeaux in Relation to the Development of Injury. Various formulae were used for making the bordeaux used in the several experiments with cherries but they were not compared directly in any single experiment so that it will not be possible to make any definite comparisons. The general conclusion, however, from a study of the results is that bordeaux at any of the strengths used may cause considerable injury, and defoliation.

"ith apples, there were three

opportunities to study the effect of different strengths of bordeaux. At Morrice (Experiment 10) 2-4-100 and 6-12-100 bordeaux were used but without any significant differences in results. Two strengths were used at East Lansing in 1923 (Experiment 6) on Baldwin and Red Canada. The formulae were 8-8-100 and 6-10-100 and the stronger material caused slightly greater defoliation on both varieties than the weak,

In 1924 a more complete test was made to determine the effect of different amounts of copper sulphate and different ratios of lime. This was with Rhode Island and Duchess at East Lansing (Experiment 9).

The results for Duchess (from Table 11) and for Rhode Island (from Table 12) may be summarized as follows. This injury is expressed in terms of total leaf-fall from spurs for the season.

Material	Duchess Rhode Island	
Bordeaux, 2-2-100	7.4(3.9)	6.6(4.2)
Bordeaux 2-4-100	7.2(1.9)	5.3(2.5)
Check	5.6(0.8)	3.0(0.4)
Bordeaux 8-8-100	8.4(1.7)	6.9(2.1)
Bordeaux 8-16-100	4.9(1.5)	7.1(2.1)
Check	2.9(1.0)	2.4(0.9)
Bordeaux 8-8-100	7.6(2.4)	7.3(3.8)
Bordeaux 8-8-100 (Dalomitec)	8.3(2.1)	7.6(4.7)
Check	4.2(1.2)	3.2(2.0)
Bordeaux 8-N-100	7.3(7.0)	7.1(6.9)
Colloidal copper hydroxide	3.9(1.7)	3.1(1.2)
Check.	3.3(0.8)	2.2(1.2)

The leaf-fall during the last period, ending October 3, may have been affected to a certain extent by frost injury so in order to avoid this complication the amount of the leaf-fall occurring up to August 20, the end of the second period, is given in parentheses for each item. An analysis of the data in this tabulation results in nothing definite except that bordeaux with only enough lime to precipitate the copper is unsafe and that colloidal copper hydroxide caused, in this instance, no foliage injury of consequence.

The only conclusion that can be drawn from this discussion of strengths of bordeaux

in relation to foliage injury is that even when the concentration is low severe injury may develop. However, the work along this line is not extensive enough or the results definite enough to permit the statement that reducing the amount of copper sulphate or increasing that of lime will or will not reduce the degree of foliage injury and defoliation.

The Relation of Shading to Lime-Sulphur Injury. The results obtained from the work where trees were shaded in comparison with unshaded trees (Experiment 6) were inconclusive and such that it is not possible to state any definite conclusions. There were no significant differences in leaf-fall under the several conditions or with spraying and no spraying and in every instance was light.

Method of Application and Foliage Injury. One object of the work in Experiment 6 was to determine if the method of application effects in any way the amount of foliage injury and leaf-fall. The materials were applied in

three ways: -- to the upper leaf surface only, to the lower leaf surface only, and to both the upper and lower surfaces.

The results with lime-sulphur on Baldwin (Table 7) were entirely inconclusive but with Red Canada (Table 8) the amount of injury increased with the different treatments in the order following: upper surface only, lower surface only, and upper and lower surfaces. The leaf-fall on the check was slightly less than where the upper surface only was sprayed. These results, however, are to be considered as indicative of what may occur rather than as conclusive evidence.

With bordeaux, 8-8-100, on Baldwin (Table 7) the degree of leaf-fall increased in the order given for the several treatments: -- check (1.6), upper surface only (3.3), lower surface only (3.8), and both upper and lower surfaces (5.0). With Red Canada (Table 8) the results were in the same order except that the leaf-fall where sprayed on the lower surface only was less than for the upper surface only. The amounts of defoliation per spur for the several treatments were as follows: -- check (1.3), upper surface only (3.3), lower surface only (2.1), and both upper

and lower (6.6). The results here must again be considered as indicative rather than conclusive as there were factors, other than method of application, that may have affected the results.

Comparative Susceptibility of Cherries and Apples to Injury by Spraying Materials. A study of the results of the several experiments with apples and cherries shows that there are rather distinct differences in the tolerance of the two fruits to lime-sulphur and bordeaux. Sour cherries, under Michigan conditions, do not seem to be subject to either of the two types of injury resulting from the use of lime-sulphur and acid lead arsenate but are quite susceptible to injury by bordeaux. Apples, on the other hand, are quite susceptible to both types of injury that may result from the use of lime-sulphur and lead arsenate. Injury following the use of bordeaux is also likely to occur on apples but usually to a less serious extent and frequently so late in the season that the effect of the defoliation following the injury may not be

- 126 -

of so much consequence as if the injury had developed early in the season.

Summary

The studies reported in this paper were made in connection with ten individual experiments on apples and sour cherries. These experiments were with trees of various ages, of several varieties, located in different parts of the state, and in two seasons that were widely different with regard to weather conditions. The conclusions drawn from these studies are summarized in the following paragraphs.

Foliage injury of two distinct types has been observed on the apple following the use of lime-sulphur and lead arsenate. The first and perhaps most common is the yellow-leaf injury which develops within one to two weeks after an application. This injury is probably caused by soluble forms of arsenic resulting from reaction between lime-sulphur and acid lead arsenate. The other injury has been called the brown-leaf or scald type and it also develops soon after an application. This injury is supposedly caused by the lime-sulphur itself and therefore might develop when it is used alone without lead arsenate. Leaf-fall

may follow both types of injury.

Bordeaux may cause on apples and cherries what has been called yellow-leaf injury. There are other types but they have not been observed to cause defoliation. Leaves affected in this way look very much like those attacked by certain leaf-spot diseases, as cherry leaf-spot.

The sour cherry shows large differences in susceptibility to injury by various spraying and dusting materials. Lime-sulphur has caused very little injury to the foliage and no serious leaf-fall. Bordeaux has frequently been responsible for heavy defoliation. Injury following the use of sulphur dust and copper dust has not been observed on the sour cherry in Michigan. Pyrox has caused very heavy defoliation. Changing from lime-sulphur to bordeaux or vice versa has resulted in quite severe foliage injury. The conditions under which such injury is likely to develop are not fully understood.

There is evidence that there is some relation between the nutritive condition of the tree and its susceptibility to bordeaux

injury but just what the conditions are that favor injury have not been determined.

The apple also varies in its susceptibility to injury by different materials but in a different way from the sour cherry. Both types of injury which may follow the use of lime-sulphur and lead arsenate have been observed. Bordeaux injury also occurs on the apple. Sulphur and copper dusts have not caused any foliage injury. The addition of excess lime to the lime-sulphur-lead arsenate combination seems to decrease slightly the amount of yellow-leaf injury but to increase that of the brown-leaf type. Calcium caseinate has caused a definite increase in the amount of brown-leaf injury and its relation to the yellow-leaf type has not been fully determined. Dry-mix sulphur-lime and colloidal sulphurs cause relatively little defoliation.

Yellow-leaf injury probably occurs on the apple more frequently than the brown-leaf but the latter may be more severe when conditions are favorable for its development.

Brown-leaf injury seems to occur under conditions that favor the growth of a tender leaf, that is, one with a light cuticle. Some of the conditions that evidently favor this are low temperature, with much precipitation at frequent intervals, relatively little sunshine, and high humidity.

Brown-leaf lime-sulphur injury in the apple was more severe with strong lime-sulphur than with weak; it was also greater with each increase in dosage, and varied closely with the actual amount of lime-sulphur concentrate used per tree regardless of the dilution or rate of application. Little or no correlation could be established, under the same conditions, between the amount of yellow-leaf bordeaux injury and the strength of the bordeaux, the rate of application or the actual amount of copper applied per tree.

Abscission of the fruit in the apple is affected by spraying materials, the results varying with different varieties. The exact relation of all materials to this phenomenon has

not been established but the results indicate definitely that lime-sulphur may, under some conditions and with some varieties cause an abnormal drop of fruit. The effect of the addition of excess lime or calcium caseinate to lime-sulphur has not been determined fully. Bordeaux and the less active sulphur sprays, as dry-mix sulphur-lime and colloidal sulphur apparently do not cause an abnormal drop.

The length of time after an application before injury develops varies with the material. Yellow-leaf and brown-leaf injury on lime-sulphur sprayed trees both develop within one to two weeks after an application and have not been observed to recur until after another application. Yellow-leaf bordeaux injury may occur soon after an application but usually has not developed until some time after and may continue or recur.

The relation of weather conditions to the time of development of injury on lime-sulphur sprayed trees is not clear, but the appearance of bordeaux injury of the yellow-leaf type in epidemic form usually follows a period of heavy fogs or light rains with the temperature relatively high.

All bordeaux injury to the foliage, however, cannot be explained in this way.

The relation between the strength and composition of bordeaux and the degree of foliage injury has not been established but it was observed that injury occurred on both apples and cherries regardless of the strength or composition of this bordeaux.

The effect of shading on the occurrence of lime-sulphur injury on apples was not determined as there was so little leaf-fall under any condition that comparisons were impossible.

The results obtained with regard to method of application in relation to leaf-fall indicate, with both lime-sulphur and bordeaux, that injury is more likely to occur when the under surface only is sprayed than when the upper surface only is covered and still more may follow a complete application to both surfaces. The results, however, are indicative rather than conclusive.

Differences were found in the susceptibility of the sour cherry and the apple to various

types of injury. The cherry seems very resistant to lime-sulphur injuries, but susceptible to bordeaux injury. The apple is susceptible to both types of lime-sulphur injury and to bordeaux injury but with bordeaux defoliation is likely to be much less severe and to occur at less critical periods than with the cherry.

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