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Spray Injury Studies. I

INJURIES FROM SUMMER APPLICATIONS ON APPLES

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TABLE OF CONTENTS

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Insect and fungus control in the orchard depends on the use of materials which are destructive to insects or fungi, and it is desirable, at the same time, that they be non-injurious to the trees thus protected. Materials which combine these qualities are rare. Even the generally used materials fall short of being innocuous. In aggravated cases, the injury induced by standard protective materials may exceed that caused by the pests against which they are designed to afford protection. Again, these same materials may be wholly harmless to the tree. Consequently, a study of circumstances attending injury may help to prevent recurrence of these injuries. A comprehensive investigation of spraying materials should include studies of fungicidal and insecticidal values and a study of the injuries that may result from their use and the effect of these injuries on the performance of the plant.

A series of experiments to determine the fungicidal value and the injurious effects of several materials and combinations of materials has been in progress for several years. A recent publication (13) contains the results obtained with these materials in the control of apple scab. This report presents the results from these, and other, experiments concerning the injurious effects of the materials used. Most of these studies and observations on injury from spraying materials were made in orchards at Morrice, Belding, and Grand Rapids. Descriptions of these orchards may be found on pages 14, 18 and 19. Other observations have been made at East Lansing, as well as in many other orchards in various parts of the State.

DESCRIPTIONS OF MATERIALS

That there may be a clear understanding of the terms used in this report, descriptions of some of the materials used are given here.

Lime-sulphur—The standard, commercial liquid concentrate testing 32 to 33 degrees Baumé.

Dry Lime-sulphur—The powdered or dry form of lime-sulphur is made by dehydrating the liquid concentrate and contains compounds of sulphur similar to those found in liquid lime-sulphur. For use as a spray, it is dissolved in water. Dry lime-sulphur is distinct from dry-mix sulphur-lime. Two brands of dry lime-sulphur were used in these experiments.

Dry-mix Sulphur-lime—A mechanical mixture of sulphur, hydrated lime, and some wetting agent such as casein spreader. This preparation is frequently called simply "dry-mix." It is mixed with water and applied as a spray. Many manufacturers of spraying materials offer, under trade names, preparations that are essentially the same as "dry-mix."

Wettable Sulphur—Sulphur to which has been added some material to make it wettable, that is, to permit its being mixed with water. Ordinary sulphur does not mix easily with water. Wettable sulphur differs essentially from "dry-mix" in that it contains little or no hydrated lime.

Colloidal Sulphur—A very finely divided sulphur which is supposed to have special merit because of the extreme fineness of the particles.

Flotation Sulphur—A recently developed product obtained as a by-product from the manufacture of gas. It is characterized by extreme fineness of the particles.

Casein Spreader—A mixture of powdered casein and hydrated lime.

Lime—Two kinds of lime have been used in this work, quick lime and hydrated lime. The kind used is indiciated in each instance. The quick lime was high calcium lime. Some of the hydrated lime has been the fine, finish lime but in 1928 and 1929 a high calcium lime specially prepared for spraying purposes was used.

Iron Sulphate—The iron sulphate used was ferrous sulphate. The crystalline form was used until 1929 and 1930, when, for part of the work, the "sugar" or granulated form was used. The crystals were always dissolved into a stock solution before use. The "sugar" grade was dissolved by addition to water in the sprayer tank with agitation. The usual procedure was to add the ferrous sulphate, lead arsenate, and lime-sulphur in the order named.

Aluminum Sulphate—The aluminum sulphate, the commercial grade obtained as a rather fine powder, was washed into the tank through the screen, since it is not easily made into a stock solution.

Calcium Sulphate—Gypsum, or calcium sulphate, was used in one instance. This was finely ground and only the portion passing through a 200 mesh screen was used. Some of the material was finer than 300 mesh.

Tobacco Dust—The tobacco used in this series of experiments contained, according to the producer's statement of analysis, one-half of one per cent actual nicotine and was of 100 mesh grade.

Lead Arsenate—The dry or powder form of the ordinary or acid lead arsenate was used in all experiments.

TYPES OF INJURY

Injuries to the fruit and foliage of the apple caused by lime-sulphur, bordeaux, arsenicals, and other materials are of many kinds. These types are sometimes distinct and easily recognizable; at other times, it is difficult to distinguish one from the other. Injuries from spraying materials and those from drought, frost, disease and other causes, are frequently so similar as to cause confusion in diagnosis. Many of these injuries have been recognized and described but since they are frequently unrecognized or improperly identified several of the more important types of spray injury are described together with other injuries that are frequently confused with spray injury. Notes on observations concerning environmental and other factors that influence their occurrence are also included.

Injuries from Lime-Sulphur

Lime-sulphur may cause certain types of injury to the apple when used alone and still other forms of injury may follow where it is combined with other materials, such as lead arsenate. Lime-sulphur injury to foliage may take the form of a definite burn; it may cause stunting or dwarfing of growth, apparently without definite burn; or burning and stunting or distortion may occur together.

Lime-sulphur Burn—Lime-sulphur injury was studied intensively soon after Cordley (8, 9, and 10) reported that lime-sulphur would control apple scab. Wallace (25), Scott (22), and others have made important contributions to the problem of lime-sulphur injury. Lime-sulphur when applied to the foliage of the apple may cause a definite burn which causes the death of the injured portions of the leaves. These areas become brown. They may be small and scattered over the leaf, or they may be large and of irregular form. Large injured areas are often marginal or at the tip of the leaf, but, in cases of severe injury, entire leaves are killed. Saprophytic fungi often invade the injured areas.

This type of injury, as it appears in a moderately severe form on fully developed leaves, is shown in Figure 1. It is most common during midsummer, but often occurs with petal-fall or early summer applications and even with the delayed dormant, prepink, and pink applications. When resulting from delayed-dormant and prepink applications, it is likely to take the form of tip-burn and the injured portions of the small, partly developed leaves turn brown or simply dry out without much browning. In more severe cases, the entire small leaves may be killed and blossom-bud development checked. In a few instances, where severe injury has occurred from the pink application, entire blossom clusters have been killed or checked; or, if the blossoms are partly open, the petals are killed. Injury caused by preblossom applications is shown in Figure 2. Lime-sulphur injury usually becomes evident within one to four days after the spray has been applied.

Wind Injury—Injury by high wind is often confused with lime-sulphur burn and distinction between the two is sometimes difficult. Wind injury, however, is usually localized in that portion of the tree directly toward the wind or in portions of the orchard most exposed. The injured areas are usually not so well defined as those resulting from lime-sulphur. This injury most frequently occurs in the early summer when the leaves are tender. Wind injury to foliage late in the season usually presents a different appearance, the leaves seeming to be bruised and discolored, while the injury to tender leaves in early summer is probably the result, in part at least, of desiccation.

Factors Affecting Lime-Sulphur Burn

Temperature—In general, the higher the temperature the greater the danger of lime-sulphur burn. In 1928, at Morrice on August 8, lime-sulphur used at the rate of 2½ gallons in 100 gallons of spray caused very severe injury to foliage. The temperature at the time of application (11 a. m.) was 89° F. and rose to 94° F. during the afternoon. The seriousness of this injury is shown in Figure 3. In 1929, at Belding, in the petal-fall and two weeks applications, dry and liquid lime-sulphur both caused serious burning during periods of high temperature, while the same materials applied

Cordley (9) and Wallace (25). Observations over a period of several years indicate that young leaves and those developing during periods of relatively low temperature, high humidity, and with the amount of sunlight below normal are more susceptible to lime-sulphur injury, if subsequent hardening has not occurred, than leaves that have been hardened by age or by high temperature, low humidity, and much sunlight.

It often has been observed that lime-sulphur injures young or tender leaves at temperatures lower than those injurious to mature and hardened leaves. In 1929, in Michigan, there was rather abundant and well distributed rainfall during the preblossom and blossom periods. Leaves developed rapidly and naturally were tender or succulent. Periods of relatively high temperature prevailed at the time of the petal-fall and two weeks applications in many parts of the state. In orchards where lime-sulphur was used during those periods, injury developed to a very serious degree. In other cases, as previously mentioned, tender foliage has been readily burned, with high humidity, but with moderate or even low temperatures.

However, as mentioned in the section on humidity in relation to injury, hardened foliage and low humidity are believed to have prevented injury when the temperature was very high. There are, therefore, two conditions with regard to the foliage itself which affect the amount of injury. Tender foliage seems to make injury possible when other factors are only moderately favorable for its development, and hardened foliage makes injury much less likely to develop even though other factors may be conducive.

Concentration of the Lime-sulphur—There is a definite relation between the concentration of the lime-sulphur spray and the amount of injury. In 1929, at Belding, lime-sulphur was used at four concentrations: one, one and one-half, two, and two and one-half gallons in each 100 gallons of spray. The temperature was favorable at the petal-fall application for the development of injury. Typical lime-sulphur burn developed with all concentrations but there was least with one gallon and the most with two and one-half gallons. Two brands of dry lime-sulphur were used in this experiment and each at concentrations of four, six, eight, and ten pounds to 100 gallons of spray. Injury developed as with the liquid lime-sulphur though possibly to a slightly less extent, but there was a definite relation between the concentration and the amount of injury.

In 1930, at Morrice, liquid lime-sulphur was used at the rate of one and two and one-half gallons and dry lime-sulphur at the rate of four and ten pounds in each hundred gallons of spray. Conditions at the petal-fall spray were conducive to injury. There was practically no injury with the low concentrations of either liquid or dry lime-sulphur, but with the higher concentrations of both there was noticeable injury and to about the same degree.

No definite rule can be stated as to what concentration of lime-sulphur will burn and what will not because of the many other factors that influence the development of injury.

Rate of Application—There is evidence from experimental tests that injury will develop more freely, other things being equal, with a heavy application of lime-sulphur than with a light application. Evidence of this is often seen where the application is irregular or spotted.

Oil and Lime-sulphur Combination—Certain types of oil emulsions and lime-sulphur are compatible, so far as the actual combination of the two materials is concerned, but there is definite evidence that the presence of oil with lime-sulphur renders lime-sulphur injury more severe or causes its development when lime-sulphur without oil would not produce injury. This is true of delayed dormant and summer applications. The comparative effects of delayed dormant applications of oil and lime-sulphur and lime-sulphur alone are shown in Figure 4. This combination has been used in many instances without injury in the delayed dormant application, but the margin of safety seems much narrower than with lime-sulphur alone.

Tree Vigor—The vigor of the tree is often considered to be an important factor in the development of lime-sulphur burn. The foliage of trees in low vigor is often considered to be particularly susceptible. Observations made by the writer on this point are not such that any definite statements can be made, but it is certain that trees of normal or high vigor are by no means immune to injury.

Distortion of Leaves

Lime-sulphur injury to fully developed apple leaves usually does not produce any distortion of the leaf, except for the possible rolling of killed leaves. If, however, partly grown leaves are injured, distortion almost always follows. Marginal injury to such leaves causes them to assume many unusual forms as a result of the checking of the growth at the margins while growth continues in the central portions of the leaf. Examples of distortion resulting from marginal injury caused by the petal-fall application are shown in Figures 5 and 6. The leaves shown came from trees sprayed with dry lime-sulphur (10 lbs. in 100 gallons) but liquid lime-sulphur of equivalent concentration caused about the same results when conditions at the time of the application were comparable. Slow drying, at rather low temperature, and tender foliage were the factors favoring injury in this instance. In another instance, rather mild injury from the pink application caused definite distortion of a different type, as shown in Figure 7. Liquid and dry lime-sulphur, at equivalent strengths, again caused similar amounts of injury.

Dwarfing

The young leaves, especially those that develop from blossom buds, are often dwarfed, crinkled, and blistered. The exact cause of this trouble is sometimes difficult to determine. Frost in the preblossom period and spraying materials used in that period are factors of importance in the development of this trouble. Leaf development is sometimes checked by the too frequent and too heavy application of lime-sulphur, especially at a relatively high concentration.

Frost and Low Temperature—Evidence that low temperatures are associated with the crinkling and blistering of apple leaves is found in the fact that this injury may develop on trees that have not been sprayed. Leaves so affected are badly crinkled and stunted and are often blistered. The crinkling seems to be the result of growth in the midrib and veins being checked, and the blisters are the result of ice formation within the leaf separating the upper and lower layers. The upper surface usually remains intact but the lower surface may turn brown or bleach and break. At Morrice, in 1930, temperatures were low for much of the time in the early preblossom period. The daily minima from April 15 to 26 were: 30, 32, 39, 37, 34, 34, 32, 24, 23, 27, 28, and 29 degrees F. The delayed dormant application was made on April 23 and 24 and the pink applicatoin on May 3. Typical leaves from unsprayed trees are shown in Figures 8 and 9.

A type of frost injury to the fruit of the apple that is frequently confused with spray and insect injury is shown in Figure 10. This is known to occur on unsprayed trees and, in 1930, was common in the orchard at Morrice as well as in a large proportion of the orchards in many parts of Michigan. This injury occurs on the pedicel and on the fruit immediately adjacent to the pedicel. The injured area appears as though the epidermis had been scraped away but the epidermis probably has simply been killed. The pedicel is drawn over at an acute angle towards the injured area. Apparently, the injury produces no injurious effects beyond scarring the apple; this, however, may cause serious wilting of the apple in storage. The appearance of these scars is shown in Figure 11. Many varieties have been injured in this way but Jonathan and Duchess seem particularly susceptible. This injury at Morrice in 1930 must have occurred while the blossom buds were in the delayed dormant condition and with the leaves in the blossom buds about one-fourth inch long. The daily minimum temperatures from April 21 to 26 while the buds were in that condition were 32, 24, 23, 27, 28 and 29 degrees F.; freezing temperature did not occur at any later date.

Blossom thrips (*Frankliniella tritici*) was present in large numbers in 1930 in many Michigan orchards during preblossom and blossom periods. Many growers were of the opinion that the crinkling and blistering of the leaves and the frost injury to the fruit just described were caused by this thrips but careful observations in many orchards indicate definitely that the thrips was not responsible.

Lime-sulphur and Dwarfing—Though the relation of lime-sulphur to dwarfing of foliage is not very clear, there is evidence that lime-sulphur sometimes intensifies stunting. In 1929, at Grand Rapids, the use of lime-sulphur (2½ gallons in 100) in the delayed dormant application on Duchess and Stayman caused a marked increase in stunting or made the leaves more susceptible to frost injury. The use of bordeaux at that time was not followed by an increase in dwarfing. In 1930, at Morrice, lime-sulphur caused no apparent increase in stunting on Jonathan and other varieties over that already caused by frost, but, at Belding, with Duchess and McIntosh, there was slightly more dwarfing with lime-sulphur and dry lime-sulphur than without. The results with Duchess and Stayman are shown in Figure 12 and with Jonathan in Figure 13. When greater stunting occurs following the use of lime-sulphur, there may or may not be definite burning.

The effect of simple stunting does not seem to be very serious, but if it is greatly increased by lime-sulphur injury the development of the blossoms may be checked noticeably.

Dwarfing from Later Applications—In a few instances, very serious results have followed the excessive use of lime-sulphur and lead arsenate. The most conspicous instance was in an orchard where McIntosh trees were sprayed three times before the blooming period and three times soon after, with lime-sulphur, three gallons, and lead arsenate, six pounds, with water to make 100 gallons. This spray was applied so heavily that the leaves at all times were heavily coated with spray residue. This resulted in checking the growth of leaves, in much actual injury so that the leaves were ragged in appearance, and in heavy leaf-fall during mid-summer. Leaves from these trees and from normally sprayed trees in the same orchard are shown in Figure 14. This injury also resulted in an excessive June drop of fruit and severe russeting and cracking of remaining fruits. The fruit is shown in Figure 15.

Apple Scab and Lime-sulphur Injury

Injury has often been reported as a result of lime-sulphur penetrating leaf-tissue through deep-seated scab lesions. This condition has been observed many times in this work. This injury is an effectual check to further development of scab from lesions so affected, but heavy leaf-fall may occur if the leaves are badly infected with scab. Leaves that have been injured in this way are shown in Figure 18. The same type of injury may follow the uses of other materials, also, as lead arsenate, alone or with lime-sulphur, bordeaux and sometimes arsenical dusts. Saprophytic fungi often invade injured areas as is also shown in Figure 18.

Lime-sulphur Injury to Fruit

Apples sprayed with lime-sulphur and lead arsenate are almost always smoother and of better finish than fruit of the same variety sprayed with bordeaux, though some russeting frequently occurs where lime-sulphur and lead arsenate are used (Figure 19). Observations on the use of lime-sulphur alone are not extensive, but it is believed that lime-sulphur used without lead arsenate rarely causes russeting of the fruit. There is evidence, however, that the russeting that follows the use of lime-sulphur and lead arsenate is caused by arsenic, rather than lime-sulphur.

Apples sometimes scald during mid- and late-summer in periods of high temperature. This condition is shown in Figure 16. This injury has been observed on fruit sprayed with bordeaux, lime-sulphur, and other sulphur sprays but is likely to occur to a greater extent where sulphur in some form, and especially lime-sulphur, has been used in an application during or not long before a period of high temperature.

Injury From Other Forms of Sulphur

Dry Lime-sulphur—Dry lime-sulphur has been mentioned in the foregoing pages as causing injury under some conditions. Evidence available indicates that all the types of injury caused by lime-sulphur may be produced by dry lime-sulphur, but, if the two are used at equivalent strengths, the dry will usually cause somewhat less injury of any type than the liquid.

Free Sulphur and Sodium-sulphur—Free sulphur sprays, such as dry-mix, wettable sulphur, sulphur pastes, and flotation sulphur, have not been observed, in these experiments, to cause any direct injury to foliage or to fruit except the possible association with sunscald of fruit noted in a preceding paragraph. Precautions may be necessary to prevent arsenical injury when these materials are used with lead arsenate. Compounds of sodium and sulphur are often unsafe on apple foliage, especially when combined with lead arsenate.

Arsenical Injury

Lead arsenate, the ordinary or acid form, is the arsenical most commonly used on apples. It is relatively stable but injury to fruit and foliage often follows its use, especially when it is combined with lime-sulphur or other sulphur containing sprays.

Injury to Foliage

"Yellow Leaf" Injury—Many studies of the chemical relation of lime-sulphur and lead arsenate have been made by Bradley (5), Bradley and Tartar (6), Robinson (20), Ruth (21), Cook and McIndoo (7), Thatcher and Streeter (23), Andrew and Garman (2), Young (27), and others. These studies, in general, show that some form of soluble arsenic is formed when lime-sulphur and acid lead arsenate are combined, and this soluble arsenic is undoubtedly the causal factor in the development of arsenical injury following the use of lime-sulphur and lead arsenate. The initial stage of this injury is purple or reddish spots on the leaf; but, usually, the first stage observed is a brown spot at some point on the leaf or larger and usually irregular areas that are marginal or at the tip of the leaf. It is difficult, in many cases, if not impossible, to distinguish between certain stages of arsenical injury and lime-sulphur injury. Many leaves with these brown areas persist until normal leaf fall but large numbers of them yellow and drop prematurely. Stages of the "yellow leaf" arsenical injury are shown in Figure 17. "Yellow leaf" injury, as a result of the preblossom or petal-fall applications has not been important but it does sometimes develop as a result of these applications. In such cases, the yellow leaves may not appear for several weeks. It may be noticeable after the two-weeks application and is more noticeable with succeeding applications of lead arsenate with lime-sulphur.

Yellow leaves may appear within a week or 10 days after an application but sometimes they are not noticeable until a longer period has elapsed. After the first appearance, other leaves may turn yellow over a brief period of one to two weeks or they may be in evidence almost continuously for several weeks. Leaves drop soon after turning yellow. The appearance of yellowing is usually progressive with leaves on spurs, appearing first on the small, basal leaves, then on the larger leaves. This order, however, is not without exception.

There are marked differences in susceptibility of varieties to this injury. Wagener, Rhode Island Greening, and Baldwin are very sensitive. Jonathan is also susceptible. Hubbardston is rather resistant and McIntosh is ordinarily not seriously affected.

Drought Injury—During periods of drought, many yellow leaves may develop on apple trees and this development may be largely the result of an inadequate supply of water, rather than the result of arsenical injury, although both factors may be involved in many cases. Yellow leaves also develop, throughout the season, regardless of spray treatment, even though there is no acute shortage of water. The factors responsible for this have not been determined.

Arsenical Injury to Fruit

Russeting—Russeting, as used here, refers to an injury to the skin of the apple, in which the epidermal cells or portions of the surface are killed and a subsequent formation of cork gives the characteristic russeted appearance. It may consist of light or heavy netting or may completely cover small or large areas. The exact cause of russeting on apples is frequently difficult, if not impossible, to establish. Frost and other unfavorable weather conditions are often responsible and in many instances these natural injuries are believed to have been caused by spraying materials. An example of frost injury that might easily be confused with spray injury is shown in Figure 19. One of the most recent reports concerning this injury is from McDaniels and Heinicke (19). It is true, however, that spraying materials are often responsible for all or part of the russeting found on a given lot of apples. As indicated in a preceding paragraph, lime-sulphur, as such, is believed to be unimportant in Michigan in the development of russeting; but, when lime-sulphur and lead arsenate are combined, russeting as a result of arsenical injury often develops. Russeting resulting from the use of this combination of materials is shown in Figure 20. It has been observed also where lead arsenate has been used with other sulphur preparations.

Blossom-end Injury—Arsenicals are responsible for another form of injury to the fruit. This occurs around the calyx and is called "blossom-end" injury. The cause of this injury has been rather obscure but recent work, especially that of Hartman (16), has indicated definitely that soluble arsenic is responsible. It appears as a dark brown or nearly black area around the calyx of the apple. The area may be confined closely to the calyx or may cover the entire basin. A saprophytic fungus, probably black-rot in most cases, invades the injured areas; and, because of this, black-rot has, in some instances, been considered as primary instead of secondary in nature. The rot sometimes spreads beyond the basin of the apple. Typical specimens of blossom-end injury are shown in Figure 16.

Factors Favoring Arsenical Injury

All the factors that control the development of arsenical injury to the foliage and fruit of the apple have not been determined in these experiments but there are several that are important.

Tree-vigor—Trees of high vigor have shown less yellow-leaf and blossom-end injury than trees of low vigor.

Lead Arsenate with Other Materials—The combination of other materials with lead arsenate may increase or decrease the amount of injury to fruit and foliage. Arsenical injury of all forms is probably prevented by using bordeaux with the lead arsenate. Lead arsenate used with lime-sulphur usually causes injury to foliage and may cause russeting and blossom-end injury to the fruit. Arsenical injury, as indicated by Young (27) may be more severe when lead arsenate is combined with low concentrations of lime-sulphur than with the higher concentrations such as 1 to 40. With some combinations, one type of injury may develop and others may not, indicating that different factors may be responsible for each injury. Burning of the foliage by lime-sulphur early in the season is believed to favor arsenical injury later. No russeting of the fruit and very little yellow-leaf injury has been observed when lead arsenate and free sulphur sprays have been used together, but blossom-end injury has occurred with such combinations. Rather severe injury to foliage through scab lesions has occurred from the use of wettable sulphur and lead arsenate.

The relation of casein spreader to injury is not well understood. Chemical investigations by Thatcher and Streeter (23), indicate that casein spreader should decrease arsenical injury from the use of lead arsenate with lime-sulphur. The work of Andrew and Garman (2), Goodwin and Martin (15) and Ginsburg (14) indicates, however, that casein spreader may sometimes cause an increase in soluble arsenic. The results from field experiments with casein spreader are confusing, as foliage injury has not been reduced; russeting of the fruit has been increased in some instances and decreased in others; and a form of blossom-end injury has been increased. Lime reduces russeting and possibly blossom-end injury. Iron sulphate inhibits the development of most forms of arsenical injury following the use of lead arsenate with lime-sulphur.

Bordeaux Injury

Bordeaux may cause injury to both the foliage and fruit of the apple. These injuries have been described and the factors affecting their development studied by Hedrick (17), Crandall (11), Adams (1), and others.

Injury to Foliage—Injury to foliage from the copper in bordeaux has the same general symptoms as yellow-leaf arsenical injury. The first visible stage of copper injury is purple spots, which usually turn brown as the tissues die. With properly made bordeaux, these lesions are usually small and may be on either the upper or lower surface of the leaf.

These brown spots may be the final stage of injury, in which case, affected leaves do not fall prematurely, but, in many cases, the leaves yellow and drop prematurely. The characteristic stages of copper injury are shown in Figure 1. The brown lesions may usually be found in any year if bordeaux has been used in the early summer applications. Large numbers of yellow leaves usually appear only after periods of high humidity and relatively high temperature. In other words, "muggy" weather is favorable to this injury. Yellow leaves may appear soon after an application, but their appearance may be delayed for several weeks until weather conditions become conducive. Injury to the foliage of the apple by bordeaux in Michigan is not often of consequence; in fact, bordeaux-sprayed trees usually have excellent foliage. The concentration of the bordeaux and the rate of application have not been observed to be significant factors in affecting the development of the yellow leaf type of copper injury. There have not been significant differences in the numbers of yellow leaves from light and heavy applications of either weak or strong bordeaux.

Injury to Fruit—Injury to the fruit is a form of russeting which is very similar to that caused by arsenicals with lime-sulphur and also resembles some types of frost injury. Examples are shown in Figure 21. Russeting from bordeaux, however, is usually much more severe than from lime-sulphur and lead arsenate. Injury to the fruit is a serious limiting factor in the use of bordeaux on apples. It may result from any of the early season applications. The greatest amount of russeting probably occurs from the petal-fall application, but it may likewise be severe from the pink and two-weeks applications. Russeting has, in some cases and to a slight extent, resulted from bordeaux applied in the delayed dormant and pre-pink applications.

The relation of weather to the development of russeting from bordeaux has not been studied in these experiments, but cold, rainy weather is generally considered to be favorable to its development (17). There is much difference of opinion about the relation of excess lime in bordeaux to russeting, but there is no evidence from this work that an excess of lime in bordeaux reduces russeting in Michigan. The rate of application and the concentration of the bordeaux are important. Both heavy application and high concentration favor injury and the actual amount of copper applied is apparently the real determining factor, since equal amounts of copper, no matter how applied, produce about the same amount of russeting.

Varieties differ widely in their susceptibility to russeting from bordeaux, Jonathan and Baldwin being susceptible; McIntosh is intermediate; and Northern Spy is the least susceptible of any variety observed. It is possible, in many seasons, to use bordeaux of low concentration throughout the season on Northern Spy without russeting.

EXPERIMENTAL DATA ON SPRAY INJURY

The facts that have been presented which relate to injuries of different kinds caused by the summer application of spray materials to apple trees afford some indication of both the seriousness and the complexity of the problem. Data throwing additional light on any of the factors that tend either to increase or lessen spray injury should be of interest to spray material manufacturers or distributors and to fruit growers alike. Records accumulated from spraying experiments extending over the period 1923-1930, inclusive, and conducted principally in two orchards in central Michigan—one located near Morrice and one near Belding—furnish much information on some of the forms of injury that have been mentioned and likewise on several other forms that have been rather generally overlooked. They are presented here for the purpose of (1) pointing out the magnitude of the cumulative effect of certain forms of injury and therefore the importance of reducing them to a minimum and (2) indicating ways by which they may be substantially lessened.

Experiments at Morrice

The Orchard—The orchard at Morrice, Shiawassee county, is on the farm of Geo. F. Winegar. The trees were planted in 1912 and are in a good state of vigor. The orchard, which covers about 10 acres, comprises blocks of Jonathan, Hubbardston, McIntosh, Baldwin, Wealthy, and Northern Spy as permanent trees, with Wagener fillers throughout. The blocks are so arranged that the experimental plots were run across the varieties and included as many of them as desired. During the period of the experiments, a sod of alfalfa and various grasses has been maintained. The growth was cut once or twice a year and then raked up under the trees, or sometimes has been left where cut. A liberal mulch of straw has been applied under the trees. Moderate amounts of nitrogen-bearing fertilizer around the trees, and barnyard manure in an all-over application between the rows of trees have been applied regularly on most of the orchard.

Spraying Equipment and Methods—A spraying outfit with a rated capacity of 10 gallons per minute and operated with a four H.P. engine was used for all the spraying. A single nozzle spray gun of the short type, and disc with an aperature of 9/64 inch have been used at all times, except in 1930 when a disc aperature of 12/64 (3/16) was used. The pressure maintained at the pump for each season was as follows: 1924, 300 lbs.; 1925, 1926, and 1927, 325 lbs.; and 1928, 1929 and 1930, 350 lbs. The pressure varied from these figures very little and for short periods only. In 1924, the spraying was done from the ground but since that year from an extension platform at the rear of the sprayer, about 15 inches above the ground. When spraying was done from the ground, each tree was completed as a unit; when spraying was done from the platform each row was completed as a unit.

Schedule and Dates of Applications—This orchard usually received five applications each year for scab control, the pre-pink, pink, petal-fall, two-weeks, and second brood sprays. No dormant spraying has been done. The dates of the several applications for each year are shown in Table 1.

Supplementary Materials—Nicotine sulphate (40 per cent) has generally been used in the prepink or pink application. In 1927, it was not used until the second brood spray when it was applied to reduce a heavy summer infestation of the green apple aphid. Lead arsenate has been used regularly in all applications, except the pre-pink, unless otherwise indicated in the outline for each year. The amount used was two pounds in each 100 gallons of spray in 1924 to 1927, inclusive. In 1928, 1929, and 1930, three pounds were used in the pink, petal-fall, and two week's sprays and two pounds in the second-brood application. Any exceptions in quantities are indicated with each outline.

Table 1.—Dates of Applications at Morrice.

Application	1924	1925	1926	1927	1928	1929	1930
Prepink	May 2, 3	....	....	Apr. 22*	May 2, 3	Apr. 10, 11, 12	Apr. 23, 24‡
Pink	May 15, 16	May 4, 5	May 18, 19	May 4, 5	May 9	Apr. 30, May 1, 2†	May 3
Petal-fall	June 6, 7	May 21	June 1, 2	May 25, 26	May 25, 26	May 27, 28	May 14, 15
Two weeks	June 19, 20	June 3	June 15, 16	June 8, 9	June 7, 8	June 7, 8, 10	May 27, 28, 29
Second brood	Aug. 12, 13	July 20, 21	Aug. 5, 6	Aug. 4, 5	Aug. 8, 9	Aug. 5, 6, 7	July 31, Aug. 1

*The prepink application was made on McIntosh only and all the trees of that variety were sprayed with lime-sulphur, 2½ gal., and water to make 100 gal.

†Trees of Northern Spy were in a very early "green-tip" stage at the time the prepink was applied to the other varieties and in the prepink condition when the others were in full pink. The Spy trees were sprayed again May 13, when the blossom clusters were fully separated.

‡This was really a delayed dormant with leaves about ¼ inch long.

A detailed statement of materials, concentrations, and results is presented in the Appendix in Tables 23 to 30.

Concentration and Dasage

In 1924, a part of the Morrice orchard was sprayed in a special way to determine the relation of the rate of application and the concentration of materials to the control of apple scab and to the development of injury to fruit and foliage. The data concerning scab development in this experiment have been published (12). Two materials were used, bordeaux and lime-sulphur. Lead arsenate powder was added in all applications except the pre-pink, and nicotine sulphate was included in the petal-fall application. These materials were used at different strengths which have, for this experiment, been arbitrarily termed weak and strong. The amounts or formulae used were as follows:

Bordeaux—Weak: 2-4-100 and 1 pound lead arsenate in each 100 gallons of spray.

Strong: 6-12-100 and 3 pounds of lead arsenate in each 100 gallons of spray.

Lime-sulphur—Weak: Lime-sulphur 1½ gallons, lead arsenate 1½ pounds and water to make 100 gallons.

Strong: Lime-sulphur 3 gallons, lead arsenate 3 pounds, and water to make 100 gallons.

Dosage and Methods of Application—The weak and strong lime-sulphur and the weak and strong bordeaux were applied each at three different dosages. These have been termed light, moderate, and heavy applications. The spraying was done in such a way that the moderately sprayed trees received approximately twice, and the heavily sprayed trees approximately three times, as many gallons as those lightly sprayed. The relative amounts per tree, then were as 1, 2, and 3. This was accomplished in the following way: The plots sprayed with each strength of each material were made up of three rows of trees; one row received a light application; one a moderate; and the third a heavy application. The spraying for each plot was always begun on the "heavy" row and all three rows were given a uniform, light application. The "light" row was sprayed no more. By the time the three rows were covered the material on the first and second rows had dried. They were again sprayed exactly as before so that the dosage was double that on the lightly sprayed row. As soon as the material had dried from the second covering, the "heavy" row was again sprayed. The final result was that one row received one, another row two, and the third, three light applications.

All spraying was done from the ground. The rows, as sprayed, ran north and south and the usual procedure was to drive on the windward side of the row and to complete each tree before beginning the next. On a few occasions, when the wind was blowing directly from the north or south, or approximately that, the work was accomplished by spraying one-half of each tree from one side, then returning on the other side of the row and completing each tree.

Comparative Amounts of Active Ingredients—It has been stated that the comparative amounts of dilute materials applied to the trees receiving light, moderate and heavy applications varied as 1, 2, and 3. The strong lime-sulphur was twice as strong as the weak, and the strong bordeaux was three times as strong as the weak. By considering together the dosage and the strength of the materials, it is possible to determine the comparative amount of active ingredients received by the trees under different treatments. For instance, the rows sprayed with light applications of weak and strong lime-sulphur received equal quantities of dilute material but the row sprayed lightly with the strong lime-sulphur received twice as much actual lime-sulphur as the other, since the dilute material was twice as strong. Likewise, the trees sprayed with the heavy application of bordeaux received three times as many gallons of diluted material as those given the light application, and, since the strong bordeaux was three times stronger than the weak, they received approximately nine times as much copper as those sprayed with a light application of weak bordeaux.

Actual Dosage of Dilute Materials—These comparative values are, of course, theoretical and were not obtained exactly in the orchard because of the impossibility of spraying all trees exactly alike. The dosage might be affected by wind direction and velocity, by the size of the trees, and possibly by certain other factors. The statement of the actual number of gallons applied per tree (Table 2) shows that, although there was some variation, the calculated dosages were given in a fairly satisfactory way. The greatest variation was between the plots sprayed with weak and with strong lime-sulphur.

In Table 2 is presented a complete record of the materials used, the formulae or rates of dilution, the rates of application, the actual number of gallons applied per tree, the comparative amounts of dilute materials, and the comparative amounts of active ingredients. The actual dosage records are presented in two groups, one for the pre-blossom applications which include the pre-pink and pink and one for the after-blossom applications. In the statement of comparative amounts of dilute materials per tree the value "1" is given to the smallest dosage of each material (of both strengths), which is the light application. In a like manner, the value "1" is assigned to the plot of each material which received the smallest amount of actual fungicide or insecticide. This would be, with both bordeaux and lime-sulphur, the plot receiving the light application of weak material. A detailed statement of results is presented in Table 24.

Table 2.—Materials, concentrations, rates of application, dosages and active ingredients used in special experiment.

Materials and dilutions	Rate of application	Actual number gallons applied per tree		Comparative amounts of	
		Pre-blossom applications	After blossom applications	Diluted material	Active ingredients
Weak lime-sulphur, 1½ gals. in 100 with 1½ lbs. lead arsenate.	Light	1.4	3.3	1	1
	Moderate	2.8	6.6	2	2
	Heavy	4.2	9.9	3	3
Strong lime-sulphur, 3 gals. in 100 with 3 lbs. lead arsenate	Light	1.6	2.7	1	2
	Moderate	3.2	5.4	2	4
	Heavy	4.8	8.1	3	6
Weak bordeaux, 2-4-100 with 1 lb. lead arsenate.	Light	1.6	2.4	1	1
	Moderate	3.2	4.8	2	2
	Heavy	4.8	7.2	3	3
Strong bordeaux, 6-12-100 with 3 lbs. lead arsenate.	Light	1.3	2.4	1	3
	Moderate	2.7	4.8	2	6
	Heavy	4.0	7.2	3	9

Experiments at Belding

The Orchard—The orchard at Belding, Ionia County, is on the farm of the Hall Orchards, Inc. The trees were planted in 1902, entirely of Baldwin, but a considerable number of McIntosh trees have been set to replace Baldwin trees that died out. Many of these McIntosh trees are only two or three years younger than the Baldwins. The block used for experimental spraying covers about eight acres. The orchard has been cultivated each year, except for the areas immediately under the trees. In many seasons, a cover crop of oats has been sown in the late summer. The trees, in general, are in good vigor. The experiments in this block were not continued after 1929.

In addition to the studies in this block of mature trees, observations have also been made in 1929 and 1930 in a 10-year-old block of McIntosh, Duchess, and Gano on the same farm. This orchard has had clean cultivation and was disced close to the trees before growth began.

Spraying Equipment and Methods—A spraying outfit with a rated capacity of 15 gallons per minute and operated with an eight H.P. engine was used. The spraying was all done with a spray gun of the standard, single nozzle type. In 1925, 1926, and 1927 a disc aperture of 3/16-inch and a pressure of 350 pounds were used but in 1928 and 1929 it was possible to use only a 9/64-inch disc aperature because of decreased efficiency of the pump. In 1928, the pressure could not be maintained uniformly or at as high a point as was desired. New pump and engine units were placed on this sprayer in 1930. The pressure was maintained at 350 lbs. and a disc aperture of 9/64-inch was used at all times. The spraying was done from the top of the sprayer tank except in 1928 when a long hose was used and the operator worked from the ground.

Schedule and Dates of Application—A five-application schedule consisting of the pre-pink, pink, petal-fall, two weeks, and second brood was followed in this orchard. The dates of these applications for each year appear in Table 3.

Table 3.—Dates of Application at Belding.

Application	1925	1926	1927	1928	1929
Prepink	Apr. 28, 29	May 11, 12	Apr. 22, 23	May 4, 5	Apr. 10, 11, 12, 15*
Pink	May 6, 7	May 18	May 6, 7	May 8, 9	May 6
Petal-fall	May 23, 25	June 3, 4	May 26	May 28, 29	May 29, 31
Two-weeks	June 4, 6	June 19	June 9, 10	June 11, 12	June 14, 15
Second brood	July 17, 18	Aug. 4	Aug. 5, 6	Aug. 9, 10	Aug. 5

*Rain and snow made spraying very difficult and, in fact, impossible at times, consequently this application was prolonged unduly.

Supplementary Materials—Nicotine sulphate (40%) has been used in the pre-pink application at the rate of three-fourths to one pint in each 100 gallons of spray. Lead arsenate has been used regularly in the pink, petal-fall, two weeks, and second brood sprays. It was used, previous to 1928, at the rate of two pounds in 100 gallons in all these applications but in 1928 and 1929 three pounds were used in all except the second brood spray, when the amount was reduced to two pounds. The only exceptions to this were the pink application in 1929, when six pounds to each 100 gallons were used for leaf-roller control (this was not done in the younger orchard) and, in 1928, when calcium arsenate was used, as indicated, in two plots.

A detailed tabular statement of materials, concentrations, and results is presented in the appendix in Tables 31 to 35.

Experiments at Grand Rapids

The Orchard—Tests were made at the Graham Horticultural Experiment Station in 1928 and 1929 in an orchard planted in 1919. Most of the trees were under a sod mulch system of management and were in moderate vigor. There are several varieties in the orchard and all were sprayed but records were obtained only from those indicated in the tabular statements of results.

A schedule of five applications was followed in this orchard. This consisted of the pre-pink, pink, petal-fall, two-weeks, and second brood-applications.

Supplementary Materials—Nicotine sulphate at the rate of one pint in each 100 gallons of dilute spray was used in the pre-pink, and lead arsenate was used in the pink, petal-fall, and two-weeks applications at the rate of three pounds in each 100 gallons of dilute spray and at the rate of two pounds in the second-brood application.

A tabular statement of materials, concentrations, and results is presented in Tables 36 and 37.

Presentation of Results

Other than observations on various types of foliage injury such as have been recorded on preceding pages, quantitative data on injuries to leaves have been limited largely to records of time and amount of premature defoliation. This injury to foliage has been measured largely by premature leaf-fall resulting from the injury. Leaf counts have been obtained in several ways but always from spurs that did not bear blossoms during the year the records were made. Counts were usually confined to spurs on wood two, three, and sometimes four years old. In some cases, these counts were made at intervals through the season and in others the counts were of leaves persistent at some period late in the season, but always before the fruit was harvested. An exact statement of injury to fruit is difficult, but russeting is expressed as percentages of fruit affected with light, medium, and heavy russet. The amounts of blossom-end injury and sunscald are also expressed as percentages.

Defoliation from Lime-sulphur Alone and in Combination With Other Materials

Lime-sulphur Alone—Lime-sulphur, alone or with lead arsenate, may cause severe injury to foliage under certain conditions. This injury has been designated as lime-sulphur burn. Leaves so injured may or may not drop prematurely but it is believed that injury from the arsenical commonly used with lime-sulphur is more likely to develop on leaves previously burned by lime-sulphur than on those that have not been so injured, and, because of this condition, leaves burned by lime-sulphur are very likely to drop prematurely.

Lime-sulphur alone was used throughout the season in a few instances and the results indicate that much less premature leaf-fall occurs from lime-sulphur alone than when lead arsenate is present, if the former is used in such a way that no lime-sulphur burn occurs. Reference to Table 26, Plot 6, shows that in 1926, lime-sulphur (1¼ gallons in 100) caused very little leaf-fall on Jonathan and Hubbardston. Again in 1927, lime-sulphur alone (Table 27, Plots 4 and 5) caused distinctly less leaf-fall than lime-sulphur with lead arsenate in adjacent rows (Plots 2 and 3).

Lime-sulphur and Lead Arsenate—The combination of lead arsenate and lime-sulphur often causes premature defoliation and often many leaves are seriously injured even though they do not drop prematurely. A commonly used combination is lime-sulphur, 2½ gallons; lead arsenate, 2 or 3 pounds; and water to make 100 gallons. The extent of premature leaf-fall caused by this spray, in comparison with that occuring on check trees, is shown in Table 23, Plots 1 and 9; Table 25, Plots 2, 8, and 10; Table 26, Plots 2, 9, and 14; Table 27, Plots 2 and 9; Table 28, Plots 3, 11, and 17; Table 29, Plots 2, 8, and 13; Table 30, Plots 9 and 15; Table 31, Plots 3 and 7; Table 32, Plots 4 and 10; Table 33, Plots 3 and 9; Table 34, Plots 3 and 9; and Table 35, Plot 3. In Tables 23, 25, 26, 27, 31, 32, and 33 are shown the original as well as the final count of leaves on spurs. The leaf-fall during the summer for unsprayed trees is shown in Table 4. The figures probably represent the normal, natural defoliation characteristic of the varieties in question, because injuries from insects and fungi were negligible. The leaf-fall is stated as percentages of the original number of leaves on the spurs and the percentages are averages for the seasons when records were taken in this way. The leaf-fall on trees sprayed with the indicated concentrations of lime-sulphur and lead arsenate is also shown in Table 4. These figures show the total leaf-fall during the summer from about June 1 to September 30.

Table 4.—Leaf-fall caused by lime-sulphur and lead arsenate.

Materials	Amount in 100 gal.	Total leaf-fall (per cent) during summer			
		Jonathan	Hubbardston	McIntosh	Baldwin
Check	....	3	13	6	14
Lime-sulphur Lead arsenate	2½ gal. 2 or 3 lb.	43	35	16	38

The loss of leaves from unsprayed trees of most varieties was very small and the actual reduction in leaf area was much less than the percentage loss shown because the leaf-fall was confined almost entirely to the small basal leaves on the spurs, which represent a small part of the total leaf area on a spur. However, with the trees sprayed with the lime-sulphur and lead arsenate, the percentage loss by count more nearly represents the reduction in leaf-area, as many of the larger leaves dropped. In addition to this, many of the persistent leaves were injured to a greater or less extent so that the functioning leaf area was still further reduced. This does not take into consideration any possible reduced functioning of uninjured leaves.

In some years, a continuous seasonal record was not taken but one final count, usually in September or early October was made to indicate the comparative conditions with various treatments. Such records are presented in Tables 28, 29, 30, 34, and 35. The final counts from these Tables, as well as those from Tables 23, 25, 26, 27, 31, 32 and 33 were averaged and the results presented in Table 5. These data show definitely that the combination of 2½ gallons of lime-sulphur, 2 or 3 pounds of lead arsenate, and water to make 100 gallons causes heavy leaf-fall on most of the varieties studied. It is evident, also, that varieties vary in their susceptibility to the injury or injuries that cause premature leaf-fall. Wagener is the most susceptible and McIntosh the most resistant, with Hubbardston nearly as resistant as McIntosh. The other varieties studied are subject to this type of injury though but not to the same extent as Wagener.

Table 5.—Leaf-fall caused by lime-sulphur and lead arsenate.

Materials	Amount in 100 gal.	Leaves persistent on spurs in September (average)						
		At Morrice					At Belding	
		Jonathan	Hubbard-ston	Wagener	Baldwin	Spy	McIntosh	Baldwin
Check	....	6.4	5.0	5.6	....	5.3	6.0	5.1
Lime-sulphur	2½ gal.							
Lead-arsenate	2 or 3 lb.	3.7	4.1	1.6	2.6	2.4	5.1	2.9

Lower Concenrations of Lime-sulphur and Lead Arsenate—The data just presented have to do with lime-sulphur and lead arsenate at the so-called standard concentrations. Several attempts have been made to determine the effect of lowering the concentration of one or both of the ingredients of the combination or of eliminating the lead arsenate. In 1926, at Morrice, several variations were used, as shown in Table 26, Plots 2, 6, 7, 8, and 9. The results of these tests are summarized in Table 6. These counts were usually made in September.

Another similar series was carried on at Morrice in 1927. The detailed statement of treatment and results is shown in Table 27, Plots 2, 3, 4, 5 and 9 and the results are summarized in Table 7. A third set of experiments was carried out in 1928, as shown in Table 28, Plots 3, 8, 9, 10 and 17. In this work, all plots were sprayed uniformly in the pre-blossom application. In the post-blossom applications, the lead arsenate was used at the rate of three pounds in 100 gallons in the petal-fall and in the two-weeks applications and two pounds in the second brood application on all plots;

Table 6.—Effect on premature defoliation of lowering the concentration of lime-sulphur and lead arsenate, Morrice, 1926.

Plot	Material	Amount in 100 gal.	Leaves lost from spurs (percentages of original numbers)	
			Jonathan	Hubbardston
2 and 9	Lime-sulphur Lead arsenate	2½ gal. 2 lbs.	27*	34*
8	Lime-sulphur Lead arsenate	2½ gal. 1 lb.	32	34
7	Lime-sulphur Lead arsenate	1¼ gal. 1 lb.	18	13
6	Lime-sulphur Lead arsenate	1¼ gal. none	9	14
14	Check		3	11

*Average of two plots (Nos. 2 and 9).

but the lime-sulphur was varied from one gallon to two and one-half gallons in each 100 gallons of spray. The results are summarized in Table 8. Still other data are available from the work at Morrice in 1930, as shown in Table 30, Plots 9, 12, 13, 14, and 15. In these tests, the lead arsenate was used uniformly on all sprayed plots but liquid and dry lime-sulphur were each used at two concentrations. The results are summarized in Table 9.

Table 7.—Effect on premature defoliation of lowering the concentration of lime-sulphur and lead arsenate, Morrice, 1927.

Plot	Materials	Amount in 100 gal.	Leaves lost from spurs (percentages of original numbers)
			Jonathan
5	Lime-sulphur Lead arsenate	1¼ gal. none	29
4	Lime-sulphur Lead arsenate	2½ gal. none	44
2 and 9	Lime-sulphur Lead arsenate	2½ gal. 2 lbs.	63*
3	Lime-sulphur Lead arsenate	2½ gal. 1 lb.	69

*Average of two plots (Nos. 2 and 9).

Table 8.—Effect on premature defoliation of lowering the concentration of lime-sulphur and lead arsenate, Morrice, 1928.

Plot	Materials	Amount in 100 gal.*	Leaves lost from spurs (percentages of checks)		
			Jonathan	Hubbardston	Wagener
2 and 11	Lime-sulphur Lead arsenate	2½ gal. 3 lbs.	54	37	68
10	Lime-sulphur Lead arsenate	2 gal. 3 lbs.	50	25	66
9	Lime-sulphur Lead arsenate	1½ gal. 3 lbs.	58	22	54
8	Lime-sulphur Lead arsenate	1 gal. 3 lbs.	54	25	34

*These concentrations refer to the post-blossom applications as all plots were sprayed uniformly in pre-blossom applications The lead arsenate was reduced to 2 lbs. on all sprayed plots in the second brood application.

In Table 6, lime-sulphur, two and one-half gallons, and lead arsenate, two pounds (Plots 2 and 9) and one pound (Plot 8) are shown not to have caused significantly different amounts of leaf-fall on either Jonathan or Hubbardston. Lime-sulphur, one and one-quarter gallons, and lead arsenate, one pound (Plot 7) and with no lead arsenate (Plot 6) are shown to have caused much less defoliation than lime-sulphur at the rate of two and one-half gallons (Plots 8, 2, and 9). With Hubbardston, there was no essential difference in results from one pound of lead arsenate and no lead arsenate; but, with Jonathan, the addition of one pound of lead arsenate (Plot 7) caused an absolute increase in leaf-fall of 9 per cent over that from no lead arsenate (Plot 6). The most significant and consistent difference in this group of plots is between Plots 6 and 7 which received one and one-fourth gallons of lime-sulphur and Plots 8, 2, and 9, on which two and one-half gallons of lime-sulphur were used.

The results presented in Table 7 show that lime-sulphur with two pounds of lead arsenate (Plots 2 and 9) and with one pound (Plot 3) caused only

Table 9.—Effect on premature defoliation of lowering the concentration of lime-sulphur and lead arsenate, Morrice, 1930.

Plot	Materials	Amount in 100 gal.	Leaves lost from spurs (percentage of check)
			Jonathan
9	Lime-sulphur Lead arsenate	2½ gal. 3 lbs.	11
12	Lime-sulphur Lead arsenate	1 gal. 3 lbs.*	11

*2 pounds were used in the second brood application.

slightly different amounts of leaf-fall. Lime-sulphur of the same concentration but with no lead arsenate (Plot 4) caused much less injury, and the reduction of the lime-sulphur to one and one-fourth gallons and without lead arsenate (Plot 5) produced still less leaf-fall. Lime-sulphur without lead arsenate caused an appreciable amount of leaf-fall but lowering the concentration of the lime-sulphur resulted in a marked decrease in leaf-fall.

In 1928, the lead arsenate was kept uniform but the lime-sulphur was used at four concentrations: one, one and one-half, two, and two and one-half gallons. The results presented in Table 8 show that, with Jonathan there were practically no differences; on Hubbardston, there were no significant differences except possibly for the greater leaf-fall with the highest concentration of lime-sulphur; but, with Wagener, there was a direct relation between the concentration of the lime-sulphur and the amount of leaf-fall. The results with Johathan were definitely affected by what was probably an increase in arsenical injury and yellow-leaf development in Plots 8 and 9, where the lower concentrations of lime-sulphur were used. The general condition of the foliage in these plots was very much better than in Plots 10, 2, and 11; but, in spite of this, injury of the yellow-leaf type was conspicuous and all such leaves fell at once. The greater part of this development came during late June and July. A conspicuous accompaniment of this injury in Plots 8 and 9 was the invasion of fungi into practically every injured spot. These were undoubtedly saprophytic in nature though this phase of the problem was not studied in detail. It was determined definitely* however that black-rot was not present. The total absence of these fungi from the leaves of adjacent unsprayed trees is evidence that they were not parasitic.

A fact definitely shown in Table 8 is the extreme susceptibility of Wagener to injury, the intermediate position of Jonathan, and the relative resistance of Hubbardston.

In 1930, Table 9, the leaf-fall was very much less than in many years but the results with high and low concentrations of lime-sulphur were of the same nature as shown in Table 8 for 1928. The actual amount of injured area on leaves in Plot 9 was much greater than in Plot 12, where the lower concentration of lime-sulphur was used but the loss of leaves was equal. The saprophytic fungi were just as conspicuous in Plot 12 in 1930 as in Plots 8 and 9 in 1928 and much more conspicuous than in Plot 9 (1930). Counts were not made on Hubbardston and Wagener, but their condition was better in Plot 12 than in Plot 9 and there was little of the yellow-leaf injury and none of the saprophytic fungus.

Summarizing the results presented in Tables 6, 7, 8, and 9, it is evident that despite some inconsistencies there are certain definite tendencies. The lowering of the concentration of lime-sulphur, especially with smaller amounts of lead arsenate, resulted in reduced leaf-fall. Injury does not seem to be lessened by reducing the lead arsenate but with the lime-sulphur concentration constant there is more injury with lead arsenate than without. Lowering the concentration of the lime-sulphur, but with the lead arsenate uniform, has resulted in more yellow-leaf injury on Jonathan, but not on other varieties.

Calcium Arsenate vs. Lead Arsenate—The substitution of calcium arsenate for lead arsenate because of its compatibility with lime-sulphur and because of its lower cost has been suggested frequently. This material was

*By Dr. Ray Nelson of the Section of Botany.

used in a few cases in this work and no marked difference was noted in the amount of injury. Calcium arsenate, however, is not generally accepted as being equal to lead arsenate for codling moth control. Reports of tests of calcium arsenate are found in Table 28, Plot 15; Table 30, Plot 8; and Table 34, Plots 4 and 5.

The Use of Supplementary Materials to Reduce Injury

Modifications of the combination of lime-sulphur and lead arsenate to reduce the injuries have been suggested. These modifications are supposed to eliminate or reduce the burning caused by the lime-sulphur or to check the reaction between lime-sulphur and lead arsenate and thus prevent the development of arsenical injury. Several of these modifications have been tested under Michigan conditions.

Tobacco Dust—Ground tobacco or tobacco dust was found by Thatcher and Streeter (23), in laboratory experiments, to check the formation of water soluble arsenic when lime-sulphur and lead arsenate are combined. Tobacco dust was used in this way in field tests in two orchards in 1928. The results at Morrice with Jonathan, Hubbardston, and Wagener are presented in Table 28, Plot 5, and at Belding with Baldwin in Table 34, Plot 2. These, together with those from the use of the ordinary combination of lime-sulphur and lead arsenate, are brought together in Table 10 and show that the addition of tobacco dust did not result in any significant difference in injury.

Table 10.—Effect on premature leaf-fall of modifying the lime-sulphur-lead arsenate spray with tobacco dust and calcium sulphate.

Materials	Amount in 100 gal.	Leaves persistent on spurs (in late September)			
		Jonathan	Hubbardston	Wagener	Baldwin
Lime-sulphur Lead arsenate	2½ gal. 3 or 2 lb.*	3.3†	4.7†	1.6†	2.4
Lime-sulphur Lead arsenate Tobacco dust	2½ gal. 3 or 2 lb.* 5 lb.	3.9	5.3	1.7	2.3
Lime-sulphur Lead arsenate Calcium sulphate	2½ gal. 3 or 2 lb. 4 lb.	3.5	4.6	2.0	....

*Two pounds used in the second-brood application.
†Average of two plots.

Calcium Sulphate—The use of calcium sulphate has been suggested by Mogendorf (18), as a means of inhibiting the formation of water soluble arsenic from lead arsenate. Calcium sulphate with lime-sulphur and lead arsenate was used in one test in 1928 at Morrice with Jonathan, Hubbardston, and Wagener (Table 28, Plot 4) and the results are shown in Table 10 in direct comparison with lime-sulphur and lead arsenate without the calcium sulphate. The data do not indicate any benefit from the addition of calcium sulphate.

Casein Spreader—The addition of casein spreader to the lime-sulphur-lead arsenate spray, as previously stated, is believed by some to be beneficial and by others to increase the possibilities of injury. Casein spreader has been used in several instances in this work: At Morrice in 1924, Table 23, Plot 2; 1925, Table 25, Plot 3; 1926, Table 26, Plot 3; 1930, Table 30, Plot 1; at Belding in 1925, Table 31, Plot 2; and 1926, Table 32, Plot 3. The data from all these experiments, except the one in 1930 at Morrice, are summarized in Table 11. In one instance only, with Jonathan in 1925, was there any noticeable difference in favor of casein spreader. In three cases, the results are practically the same but in the other six cases there were fewer leaves persistent where casein spreader was used. The obvious conclusion is that the addition of casein spreader to the lime-sulphur-lead arsenate spray is more likely to increase than to lessen leaf-fall.

Table 11.—The relation of casein spreader to injury from lime-sulphur and lead arsenate.

Materials	Amount in 100 gal.	Year	Leaves persistent on spurs (average)*				
			Jonathan	Hubbardston	Wagener	Baldwin	McIntosh
Lime-sulphur....	2½ gal.	1924	....	3.5 (4.5)	1.4 (2.6)	....	....
Lead arsenate....	2 lb.	1925	4.7 (3.9)*	4.6 (4.9)	....	3.6 (4.9)	5.4 (6.2)
Casein spreader..	1 lb.	1926	4.6 (4.8)	4.0 (4.6)	....	4.4 (4.5)	5.8 (5.7)

*The figures in parentheses show the results from the same concentrations of lime-sulphur and lead arsenate without casein spreader.

Cane Sugar—Cane sugar is used in the manufacture of dry lime-sulphur to inhibit the breaking down of the sulphur compounds in the lime-sulphur and it has been claimed that its presence checks the formation of water soluble arsenic when lead arsenate is used with the dry lime-sulphur. Cane sugar was used with liquid lime-sulphur and lead arsenate at Morrice and Belding in 1925 (Table 25, Plot 6 and Table 31, Plot 6). The figures obtained at Morrice (Table 25, Plot 6) with both Jonathan and Hubbardston show significantly less leaf-fall than where sugar was not used (Plot 2). At Belding (Table 31, Plot 6), there was greater leaf-fall where sugar was added than where none was used (Plot 3). Factors other than spraying materials may have been operative in increasing the injury in Plot 6. This work is not extensive enough to be conclusive but there is some indication that sugar may be of value in this connection.

Lime—The incorporation of lime in the lime-sulphur-lead arsenate spray has been advised many times to reduce spray injury. Both hydrated and quick lime have been used in these experiments. The results of these tests are shown in Table 23, Plot 3; Table 25, Plot 4; Table 26, Plot 4; Table 28, Plots 1 and 2; Table 31, Plot 4; Table 32, Plot 5; and Table 34, Plots 7 and 8. These data are brought together in Table 12. In a total of 14 comparisons, only two show marked differences and these are not in one direction. Otherwise, the data indicate that lime did not increase or decrease injury to foliage.

Table 12.—The relation of lime to injury from lime-sulphur and lead arsenate.

Materials	Amount in 100 gal.	Year	Leaves persistent on spurs (average)†				
			Jonathan	Hubbardston	Wagener	Baldwin	McIntosh
Lime-sulphur....	2½ gal.	1924	....	3.9 (4.5)	....	....	....
Lead arsenate....	2 or 3 lb.	1925	5.4 (3.9)†	4.8 (4.9)	....	4.4 (4.9)	7.0 (6.2)
Lime*.........	....	1926	5.0 (4.8)	4.5 (4.6)	....	4.6 (4.5)	6.0 (5.7)
		1928	3.4 (3.6)‡	4.1 (4.0)†	1.7 (1.4)†	1.6 (2.4)	3.3 (3.4)

*Refer to the original tables, as indicated in the text, for the amounts of lime used.
†The figures in parentheses show the results from the same concentrations of lime-sulphur and lead arsenate without lime.
‡Average of two plots.

Aluminum Sulphate—Investigations in Canada (3) have shown that the use of aluminum sulphate with lime-sulphur and arsenicals has resulted in marked improvement in certain respects. Aluminum sulphate at the rate of 3½ pounds to each gallon of lime-sulphur solution reduces or eliminates the injurious effects of lime-sulphur that are so serious in that territory. This should be expected since this amount of aluminum sulphate precipitates practically all the sulphur in solution in the lime-sulphur. This combination was used at Morrice and Belding in 1927, as shown in Table 27, Plot 8 and Table 33, Plot 4. It caused slightly less leaf-fall than the same concentration of lime-sulphur and lead arsenate, as indicated in Table 27, Plots 8, 2 and 9 and Table 33, Plots 4 and 3. The foliage on trees sprayed with the aluminum sulphate modification was of excellent color and free from lime-sulphur burn but there was a rather severe development of yellow-leaf injury, indicating that the modification does not work well with lead arsenate.

Iron Sulphate—Iron sulphate (ferrous sulphate) has been experimented with in several ways in connection with spraying materials. Examples of this are the investigations of Waite (24), who combined it with self-boiled lime-sulphur; of Ballard and Volck (4) who found lime-sulphur and iron sulphate desirable as a spray for the control of apple powdery mildew. This spray, which was known as "iron sulphide" was further tested in Oregon by Winston and Childs (26).

The combination of iron sulphate with lime-sulphur sprays to serve as a marker has been practiced to a considerable extent in certain districts. The reports concerning the use of iron sulphate have not all been in accord and little has been reported concerning it in recent years.

Investigation of the use of iron sulphate with lime-sulphur and lead arsenate began in Michigan in 1925. Iron sulphate was added in this work at the rates of one-half, one, and three and one-half pounds of iron sulphate for each gallon of lime-sulphur concentrate. The lime-sulphur was always used at the rate of 2½ gallons with water to make 100 gallons. Iron sulphate has also been combined with the lime-sulphur-calcium arsenate combination and with dry lime-sulphur and lead arsenate. Three and one-half pounds is approximately the amount of iron sulphate required to precipitate completely one gallon of lime-sulphur concentrate. One half pound, therefore, would precipitate approximately one-seventh of each gallon of lime-sulphur.

The procedure usually followed in mixing iron sulphate with the other ingredients follows: Start filling the sprayer tank with water and, when there are 25 to 50 gallons in the tank, add the iron sulphate, then the lead arsenate; and, lastly, when the tank is nearly full, add the lime-sulphur. Fill the tank with water and apply. Keep the agitator in operation at all times.

Iron sulphate was used at Morrice in 1925, as shown in Table 25, Plot 5, and at Belding, as indicated in Table 31, Plot 5. The percentage loss, by count, of leaves from spurs from four varieties is shown in Table 13. These percentages are calculated from the leaf-fall records presented in Tables 25 and 31.

Table 13.—The effect on leaf-fall of adding iron sulphate to the lime-sulphur and lead arsenate spray, 1925.

Treatment	Percentage of leaves lost from spurs			
	Jonathan	Hubbardston	McIntosh	Baldwin
Lime-sulphur and lead arsenate	48	32	16	24
Iron sulphate, lime-sulphur and lead arsenate	7	18	4	22

The premature leaf-fall when the iron sulphate was added was much less and the general condition of the foliage was much better than where lime-sulphur and lead arsenate without the iron sulphate were used.

In 1926, iron sulphate was used in the same way as in 1925, as indicated in Table 26, Plot 5 and Table 32, Plot 7. Lime-sulphur and lead arsenate, as shown for Plots 2 and 4 respectively in Tables 26 and 32, caused premature leaf-fall during the season of 31 per cent for Jonathan, 32 per cent for Hubbardston, 16 per cent for McIntosh, and 26 per cent for Baldwin. The same materials with iron sulphate added caused losses of 13, 23, 20, and 16 per cent, respectively, for the same varieties. The leaf-fall was significantly less with iron sulphate in Jonathan, Hubbardston, and Baldwin but slightly greater in McIntosh.

In 1927, iron sulphate was used at Morrice (Table 27) as in 1925 and 1926 at the rate of one-half pound for each gallon of lime-sulphur (Plot 6) and at the rate of 3½ pounds to each gallon of lime-sulphur (Plot 7). It was used in the same manner at Belding (Table 33, Plot 6). The premature loss of leaves on Jonathan at Morrice without iron sulphate (Plot 2) was 61 per cent of the original number of leaves; with one-half pound of iron sulphate to each gallon of lime-sulphur, the loss was 46 per cent; and with the iron sulphate increased to 3½ pounds, the premature loss of leaves was reduced to 35 per cent. The general appearance of the foliage in Plots 6 and 7 was decidedly better than in Plot 2 and indicated an even greater improvement than is shown by the leaf counts. At Belding, with Baldwin, the results were in line with those at Morrice. In Plot 3, where no iron sulphate was used there was a 66 per cent loss of leaves; and, in Plot 6, where it was used, this loss was reduced to 37 per cent. The larger amount of iron sulphate ($3\frac{1}{2}$ pounds) makes the spray mixture "heavy" and with poor wetting properties and probably reduces the fungicidal value. In 1927, it was observed that the use of iron sulphate in late summer is likely to cause some spotting of the fruit because the residue persists, and, further, that the arsenical residue may be undesirably high where the iron sulphate was used. Because of these conditions, it was decided that the combination of iron sulphate with lime-sulphur in the second brood application is undesirable; and, in all succeeding investigations, bordeaux and lead arsenate instead of the iron sulphate combinations have been employed for that application. Reference to the use of iron sulphate in succeeding experiments means, then, that iron sulphate, lime-sulphur, and lead arsenate were used in the earlier sprays and that bordeaux and lead arsenate were used in the second generation application.

At Morrice, in 1928, iron sulphate was used at two rates: One-half pound and one pound to each gallon of lime-sulphur, as indicated in Table 28, Plots 6 and 7, and at Belding at the rate of one-half pound with each gallon of lime-sulphur with both lead and calcium arsenate, as shown in Table 34, Plots 5 and 6. The results of these tests are brought together in Table 14.

Table 14.—The effect of adding iron sulphate to lime-sulphur with lead and calcium arsenate, Morrice and Belding, 1928.

Materials	Amount in 100 gal.	Leaves persistent on spurs (average)				
		Morrice			Belding	
		Jonathan	Hubbardston	Wagener	McIntosh	Baldwin
Lime-sulphur Lead arsenate	$2\frac{1}{2}$ gal. 3 or 2 lb.†	3.6	4.0	1.4	3.4	2.4
Lime-sulphur* Lead arsenate Iron sulphate	$2\frac{1}{2}$ gal. 3 or 2 lb.† $1\frac{1}{4}$ lb.	6.2	6.3	3.4	3.9	2.9
Lime-sulphur* Lead arsenate Iron sulphate	$2\frac{1}{2}$ gal. 3 or 2 lb.† $2\frac{1}{2}$ lb.	6.3	6.2	3.2	....	....
Lime-sulphur* Calcium arsenate Iron sulphate	$2\frac{1}{2}$ gal. 2 lb. $1\frac{1}{4}$ lb.	....	....	....	3.8	2.7

*Bordeaux was substituted for lime-sulphur and iron sulphate in the second brood application.
†2 lbs. were used in second brood application.

These data show a very much better condition at Morrice where iron sulphate was used and a noticeable difference at Belding. There was little difference at Morrice between the two amounts of iron sulphate but the general condition of the foliage was slightly better where $2\frac{1}{2}$ pounds were used. The use of iron sulphate with lime-sulphur and calcium arsenate at Belding gave practically the same results as with lime-sulphur and lead arsenate.

A study of iron sulphate was continued at Morrice and Belding in 1929 in experimental plots and it was also used by many apple growers in Michigan. An effort was made to determine (1) in which applications it is most desirable to use iron sulphate, and (2) the effect of adding casein spreader to the combination. At Morrice (Table 29), iron sulphate was added in Plot 5 in the pre-pink, pink, petal-fall, and two weeks applications; in Plot 6, it was omitted in the pre-pink; and, in Plot 4, it was not included until the two-weeks application. In Plot 3, casein spreader was used with iron sulphate in the pink, petal-fall, and two weeks applications. In Plot 10, dry lime-sulphur A was substituted for liquid lime-sulphur. At Belding (Table 35, Plot 4), iron sulphate was included in all the early applications. It was also applied in several combinations in another orchard at Belding. The results of this experiment are not reported in detail as none of the injury that was to be studied developed under any treatment.

Leaf-fall, at Morrice, was significantly reduced by the addition of iron sulphate, as shown in Table 29, where Plots 4, 5, and 6 all show a larger number of leaves persistent than in Plot 2 where no iron sulphate was added. Leaf counts are presented here for five varieties—Jonathan, Hubbardston, Wagener, Baldwin, and Spy. The omission of iron sulphate in one or more of the early applications (Plots 4 and 6) did not materially change the results from those obtained in Plot 5. The inclusion of casein spreader (Plot 3) did not have any marked effect on leaf-fall. At Belding, (Table 35) leaf-fall was severe both with and without iron sulphate but was distinctly worse where iron sulphate was not used (Plot 3) than where it was (Plot 4).

Dry lime-sulphur (Table 29, Plot 7) caused slightly less leaf-fall than lime-sulphur (Plot 2). The inclusion of iron sulphate with dry lime-sulphur (Plot 10) produced effects not greatly different from those obtained in Plot 5 where iron sulphate was employed in the same way with liquid lime-sulphur.

There were several periods during 1929 when conditions were very favorable for true lime-sulphur burn, and, at both Morrice and Belding, iron sulphate at the rate of one-half pound to each gallon of lime-sulphur failed to prevent this injury. It is obvious, therefore, that there can be no advantage in adding iron sulphate in this proportion when lead arsenate is not used. It is further evident that the inclusion of iron sulphate is less important in the pre-blossom applications and that it is probably most important, to reduce foliage injury, in the two-weeks application or any time soon after that when lime-sulphur and lead arsenate are used.

The investigations with iron sulphate were continued in 1930 at Morrice, as shown in Table 30. Iron sulphate was used in Plot 6 in all applications except the second brood application, and, in Plot 7, it was not included until the two-weeks application. In Plot 8, calcium arsenate was substituted for lead arsenate; in Plot 2, NuRexform lead arsenate was substituted for the regular lead arsenate; in Plot 1, casein spreader was added; and, in Plot 5, dry lime-sulphur A was substituted for liquid lime-sulphur. Leaf-fall was about the same in all these plots. The number of leaves persistent in four of these plots was 4.4 and in two there were 4.6. Lime-sulphur and lead arsenate without iron sulphate (Plot 9) caused the loss of more leaves than occurred in any plot with iron sulphate. The premature leaf-fall with the regular lime-sulphur-lead arsenate spray was much less in 1930 than in most preceding years. These results indicate, as did those of 1929, that the injury that is prevented by iron sulphate follows the after blossom applications.

The data just summarized show definitely that the addition of iron sulphate to lime-sulphur (2½ gallons in 100) and lead arsenate results in significantly better foliage than when the same concentration of lime-sulphur and lead arsenate without iron sulphate is used. This improvement is shown by a reduction in premature leaf-fall and by a much better condition of the persistent leaves. Most of the benefit results from the inclusion of iron sulphate in the after-blossom applications, which are the ones most often followed by yellow-leaf injury. This indicates that the better condition of the foliage is the result, in part at least, of checking arsenical injury resulting from the soluble arsenic formed when lime-sulphur and lead arsenate are combined rather than by reducing true lime-sulphur burn. The results of 1929 show that one-half pound of iron sulphate to each gallon of lime-sulphur does not prevent the lime-sulphur injury. Complete chemical studies of the effect of iron sulphate on the lime-sulphur and lead arsenate spray have not been made but analyses indicate that the formation of water soluble arsenic is checked when iron sulphate is present.*

Dry Lime-sulphur—Dry lime-sulphur has been used in many of these experiments. The value in the control of apple scab has been discussed in a previous publication (13). The way in which dry lime-sulphur has been used is indicated in Table 25, Plot 7; Table 26, Plots 11, 12, and 13; Table 29, Plot 7 and 10; Table 30, Plots 5, 13, and 14; Table 32, Plots 8 and 9; Table 33, Plots 7 and 8; and Table 35; Plot 2.

At Morrice, in 1925 (Table 25), dry lime-sulphur A (8 pounds in 100) caused about the same amount of leaf-fall (Plot 7) as liquid lime-sulphur (2½ gallons in 100) in an adjacent plot (Plot 8). In 1926, dry lime-sulphur A was used at three concentrations: 6, 8, and 10 pounds in 100 gallons. There was little difference in results on Jonathan but with Hubbardston there was a direct relation between concentration and leaf-fall, 10 pounds in 100 causing the greatest loss of leaves and 6 pounds the least, (Table 26, Plots 11, 12, and 13). Liquid lime-sulphur at the rate of 2½ gallons in 100 (Plot 9) caused about the same amount of leaf-fall on Jonathan as dry lime-sulphur and on Hubbardston slightly more than the approximate fungicidal equivalent of the dry (10 pounds in 100). In 1929 (Table 29), a comparison of dry lime-sulphur (Plot 7) and liquid lime-sulphur (Plot 8) used at equivalent strengths shows rather heavy leaf-fall with both but slightly greater with the liquid.

Dry lime-sulphur with iron sulphate (Plot 10) in the early applications and bordeaux in the last caused, on the average, about the same results as liquid lime-sulphur used in the same manner (Plot 4). In 1930 (Table 30, Plots 13 and 14), the use of dry lime-sulphur at two concentrations caused less leaf-fall than comparable concentrations of liquid lime-sulphur (Plots 12 and 9). Accurate comparisons are impossible, however, because the results obtained on different trees within the plots sprayed with dry lime-sulphur were extremely variable. Factors other than spraying materials were involved. In Plots 5 and 6, dry and liquid lime-sulphur with iron sulphate produced identical results.

At Belding, in 1926 (Table 32), dry lime-sulphurs A and B at the rate of 10 pounds in 100 gallons (Plots 8 and 9) caused slightly more leaf-fall than liquid lime-sulphur of comparable concentration (Plot 4). In 1927, at Belding, the results were almost identical (Plots 3 and 7) and the same condition prevailed in 1930 (Table 35, Plots 2 and 3).

*By O. B. Winter of Section of Chemistry of Michigan Agricultural Experiment Station.

These data indicate that liquid and dry lime-sulphur, used in amounts comparable fungicidally, cause about equal amounts of leaf-fall, but a comparison of the condition of the persistent leaves often indicates better results with dry lime-sulphur.

DEFOLIATION FROM SULPHUR SPRAYS OTHER THAN LIME-SULPHUR

Several sulphur sprays, other than liquid and dry lime-sulphur, were used in these investigations. Among these, were dry-mix sulphur-lime, wettable sulphur, colloidal sulphur, flotation sulphur, and calcium monosulphide.

Dry-mix—Dry-mix was used at Morrice in 1924 as indicated in Table 23, Plots 4 and 5. In Plot 4, it was used throughout the season. It was used in Plot 5 for the after-blossom applications, lime-sulphur having been used in the preblossom period. The amount of leaf-fall was small in both plots and less than with lime-sulphur in Plot 1. Dry-mix was used also at Belding in 1927 in the after-blossom applications after lime-sulphur in the pre-blossom period (Table 33, Plot 2). Leaf-fall was less and leaf condition better than in Plot 3 where lime-sulphur was used throughout the season.

Wettable Sulphur—A wettable sulphur was used at Morrice in 1926 (Table 26, Plot 1) in the two-weeks and second-brood application following lime-sulphur in the petal-fall and earlier applications. The amount of leaf-fall was distinctly less with both Jonathan and Hubbardston than where lime-sulphur was used throughout the season (Plot 2). There was, however, some yellow-leaf injury following the last spray. Lime in the mixture might have prevented this. A wettable sulphur was used in 1927 at Morrice, as indicated in Table 27, Plots 11 and 12. Leaf-fall was severe in both these plots and occurred to about the same degree as on lime-sulphur sprayed trees. The injury that caused the loss of leaves was of the yellow-leaf type. This material was ineffective in scab control and a high percentage of the leaves were affected by scab. Lead arsenate was used with the wettable sulphur and it is probable that the severe development of yellow-leaf injury resulted from arsenical injury through the scab lesions.

Colloidal Sulphur—Colloidal sulphurs from different sources were used in 1924 at Morrice, as shown in Table 23, Plots 6 and 7. No leaf-fall of consequence occurred with either but neither controlled scab in a satisfactory manner.

Flotation Sulphur—Flotation sulphur was used at Morrice in 1928 (Table 28, Plot 16). Trees sprayed with this maintained excellent foliage throughout the season. A further test of the same product was made again at Morrice in 1930 (Table 30, Plot 3). The foliage again remained in excellent condition throughout the season.

Calcium Sulphide—A recently introduced material, calcium sulphide (Cal-Mo-Sul), was used at Morrice in 1930, as shown in Table 30, Plot 4. There was no evidence of injury to the foliage.

Sulfocide—A sodium-sulphur compound, known as Sulfocide, was used in several experiments in the early part of these investigations. Casein spreader was always added to the spray when lead arsenate was used. This was in accordance with the manufacturer's instructions, to reduce the formation of water soluble arsenic when the sodium sulphide was combined with lead arsenate. Sulfocide was used at Morrice in 1925 (Table 25, Plot 1), at Belding in 1926 (Table 32, Plot 6) and in 1927 (Table 33, Plot 5). Leaf-fall was greater at Morrice in 1926 than with lime-sulphur but was slightly less at Belding in 1926 and 1927. Since this material was found to be ineffective in the control of apple scab, investigations with it were discontinued.

Foliage Injury from Copper Sprays

Bordeaux—Bordeaux has been used continuously on one plot at Morrice and on one plot at Belding. Lime-sulphur or lime-sulphur and iron sulphate has been substituted for bordeaux in the petal-fall application in recent seasons in order to reduce to a certain extent the russeting on the fruit. In one year, a prepared bordeaux was substituted for the home-made material. The bordeaux used in 1925 was made according to the 4-8-100 formula and this material has been used since at a concentration as low as 2-2-100. The concentration used each year is indicated in the proper table in the appendix. The plots that have had bordeaux used continuously have uniformly had very light leaf-fall and the foliage has almost always remained in excellent condition throughout the season. The results are shown in Table 23, Plot 8; Table 25, Plot 9; Table 26, Plot 10; Table 27, Plot 10; Table 28, Plot 12; Table 29, Plot 9; Table 30, Plot 10; Table 31, Plot 1; Table 32, Plot 2; and Plot 1 in Tables 33, 34, and 35. The condition of the foliage in these plots is compared with that in plots sprayed with lime-sulphur and lead arsenate for each year in Table 15.

Table 15.—Comparative foliage condition with bordeaux and lime-sulphur.

Year	Leaves persistent on spurs (September)									
	Jonathan		Hubbardston		Wagener		McIntosh		Baldwin	
	Bordeaux	Lime-sulphur	Bordeaux	Lime-sulphur	Bordeaux	Lime-sulphur	Bordeaux	Lime-sulphur	Bordeaux	Lime-sulphur
1924	....	....	5.8	4.5	4.0	2.6	....	....	....	....
1925	7.7	4.6*	6.5	4.9*	....	....	6.7	6.2	5.7	4.9
1926	6.6	5.0*	6.9	4.6*	....	....	7.7	5.7	4.8	4.5
1927	5.0	2.7*	....	....	....	....	....	....	4.4	1.8
1928	6.2	3.3*	6.5	4.7*	3.1	1.6*	....	....	3.6	2.4
1929	3.8	2.3*	4.3	2.4*	3.7	1.3*	....	....	3.9	1.2
1930	4.9	4.1	....	....	....	....	....	....	....	....

*Average from two plots.

These data show in every instance that there has been a greater number of leaves persistent with bordeaux than with lime-sulphur, and, furthermore, the condition of the persistent leaves on the bordeaux trees was always better than where lime-sulphur was used.

Bordeaux has been used, beginning in 1928, in the second brood application on all plots that have been sprayed in the earlier applications with lime-sulphur and iron sulphate. The results from this practice have been satisfactory and bordeaux is especially desirable at that period because it can be used when the temperature is high. Lime-sulphur is likely to cause immediate injury under such conditions and the greatest development of yellow-leaf injury usually follows the use of lime-sulphur and lead arsenate at that season. Bordeaux may be used in the second-brood application after lime-sulphur without as well as with iron sulphate. The use of bordeaux in the early summer applications is very undesirable, however, on most varieties of apples in Michigan because of the russeting of the fruit.

Other Copper Materials—In 1928, several copper compounds were used at Grand Rapids as indicated in Table 36. Leaf-counts were not made in these plots but rather heavy leaf-fall occurred from both grades of basic copper sulphate and both kinds of copper carbonate. These materials were all used in proportions such as to give approximately equal amounts of copper in the dilute spray.

SPECIAL METHODS EXPERIMENT

The investigations carried on in 1924 that involved the use of special methods, which are described on page 15 will be discussed from three points of view:—concentration of materials, rate of application, and units of active ingredients applied. The effect of these three factors on injury to foliage and fruit are considered in succeeding paragraphs.

Injury to Foliage

Concentration of Materials—Two concentrations of lime-sulphur and bordeaux were used. The lower concentration of each has been termed weak and the higher concentration strong. Lead arsenate was used at correspondingly weak and strong concentrations with both lime-sulphur and bordeaux. These concentrations are shown in Table 2, page 17.

On Hubbardston, with the light application of weak lime-sulphur (Table 24, Plot 10) there was a leaf loss of 23 per cent. Since this is almost identical with the leaf-fall on the unsprayed trees (Plot 9), it may be said that there was no injury of consequence from this treatment. The light application of strong lime-sulphur (Plot 13) caused a reduction of 44 per cent which is a significant increase. A moderate dosage of weak lime-sulphur (Plot 11) caused a loss of 35 per cent while the moderate application of strong lime-sulphur (Plot 12) caused 41 per cent of the leaves to fall and the same dosage of strong lime-sulphur (Plot 15) resulted in the severe loss of 76 per cent. The results with Wagener are very similar. With the light applications, there was a difference of 2.5 leaves per spur between the weak and strong lime-sulphur; with the moderate application a difference of 1.3 leaves per spur, and with the heavy application a difference

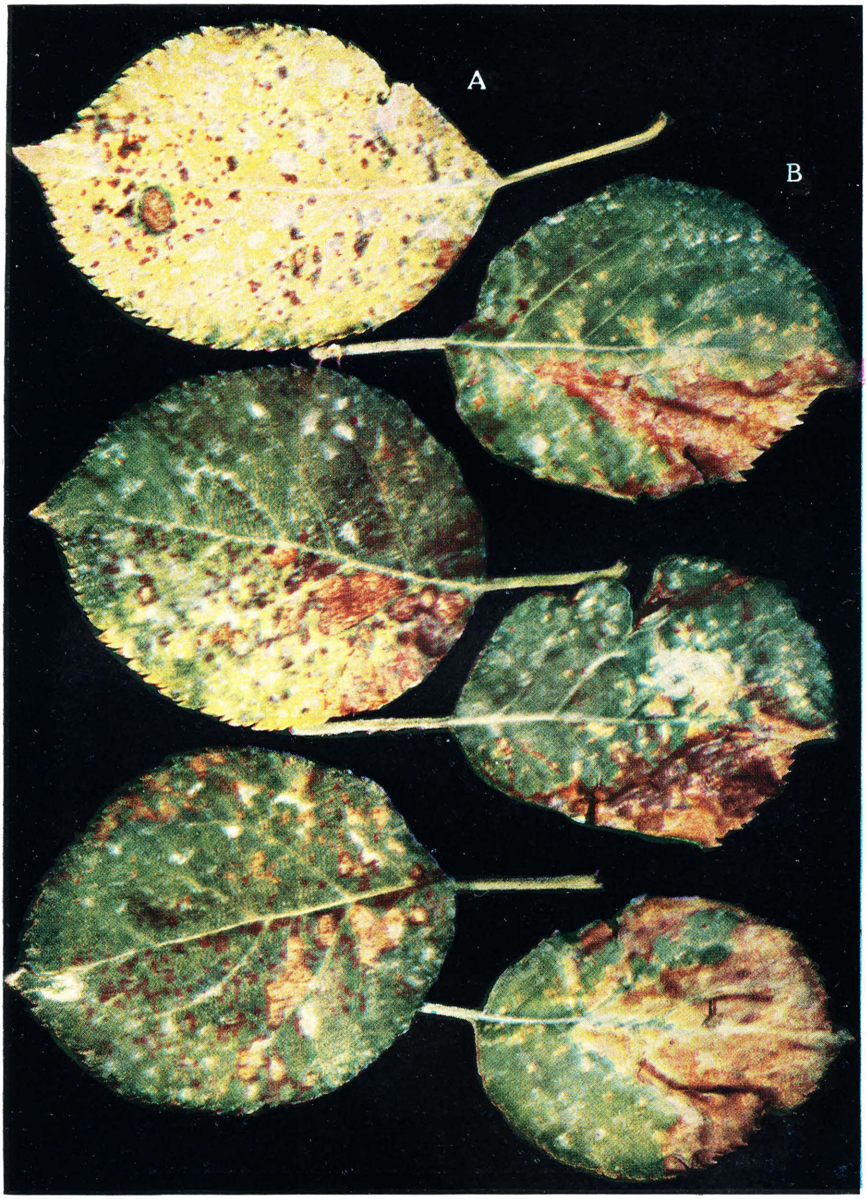

Figure 1. **Injuries to Foliage from Bordeaux and Lime-sulphur.** A. Lower leaf shows early red or purple spot stage of copper injury and with some areas dead and brown. Brown spots and some yellowing are shown on second leaf and the final yellow-leaf stage is illustrated in the upper leaf. B. Lime-sulphur burn is present on all three leaves.

Figure 2. **Lime-sulphur Injury to Young Leaves.** A. Spurs from unsprayed trees with no injury but some crinkling from frost. B. Spurs from trees sprayed with lime-sulphur (2½ gal. in 100) that dried quickly. C. Spurs from trees sprayed with lime-sulphur (2½ gal. in 100) that dried very slowly. Severe injury and stunting followed. The blossoms have been removed from all spurs.

Figure 3. **Lime-sulphur Injury to Mature Leaves.** A. Shoots from trees sprayed with lime-sulphur (2½ gal. in 100) with temperature of 89° F. B. Leaves from trees sprayed on the same day with bordeaux with temperature at 94° F. There was no injury.

Figure 4. **Injury from Lime-sulphur and Oil Emulsion.** A. Leaves from trees sprayed in delayed dormant stage with lime-sulphur (3 gal. in 100) and a commercial oil emulsion (3 per cent). B. Leaves from the same orchard sprayed in delayed dormant stage with lime-sulphur (12½ gal. in 100).

Figure 5. **Distortion of Leaves Resulting from Lime-sulphur Injury.** Marginal injury to partly developed leaves causes distortion. The injury resulted from the petal-fall application. See Figure 6 also.

Figure 6. **Distortion of Leaves Resulting from Lime-sulphur Injury.** Leaves with marginal injury assume many fantastic forms. The injury followed the petal-fall application. See Figure 5 also.

Figure 7. **Marginal Injury from Lime-sulphur and Dry Lime-sulphur.** A. Leaves from trees sprayed with liquid lime-sulphur (2½ gal. in 100). B. Dry lime-sulphur (10 lbs. in 100 gal.) was responsible for injury on these leaves. This injury was the result of the use of liquid and dry lime-sulphur in the pink application. C. No injury occurred when bordeaux was used under similar conditions.

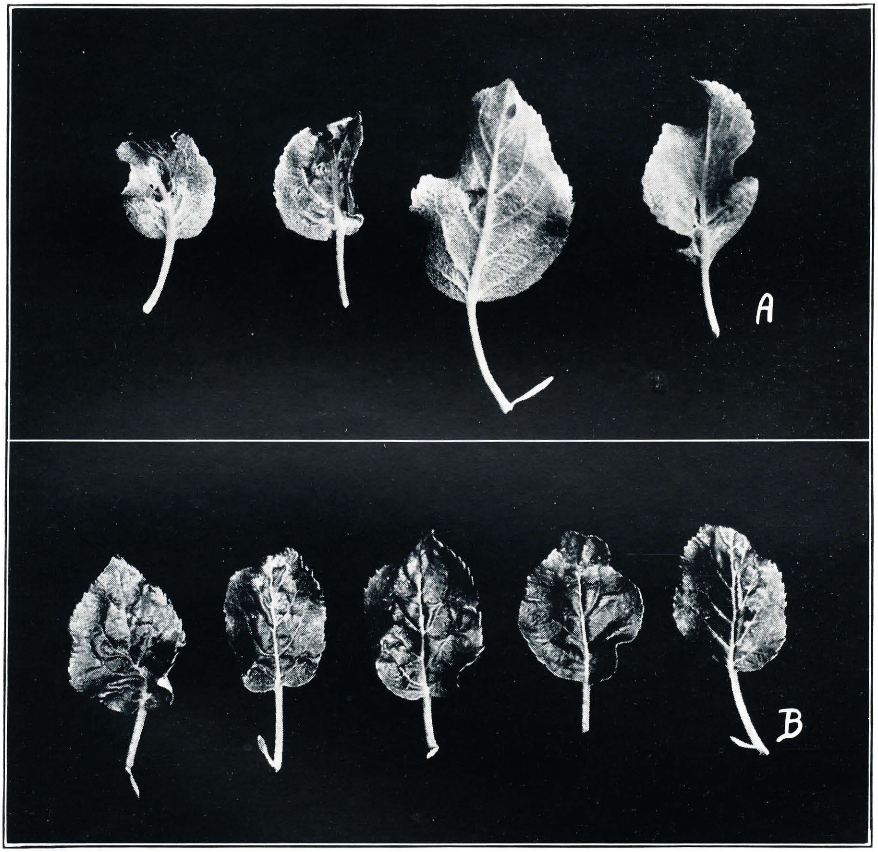

Figure 8. **Frost Injury to Leaves.** Freezing during the early pre-blossom period often causes blistering and cracking of the leaves as shown at A and crinkling of the whole leaf as in B. See Figure 9 also.

Figure 9. **Frost Injury to Leaves.** Frost injury often causes severe crinkling, blistering and stunting of the leaves that come with the blossoms. In A is shown the condition typical of the pre-blossom and blossom period; in B is presented the condition found about two weeks after petal fall. New normal leaves have developed and many of the old, crinkled leaves have yellowed and fallen. These spurs are all from unsprayed Jonathan trees.

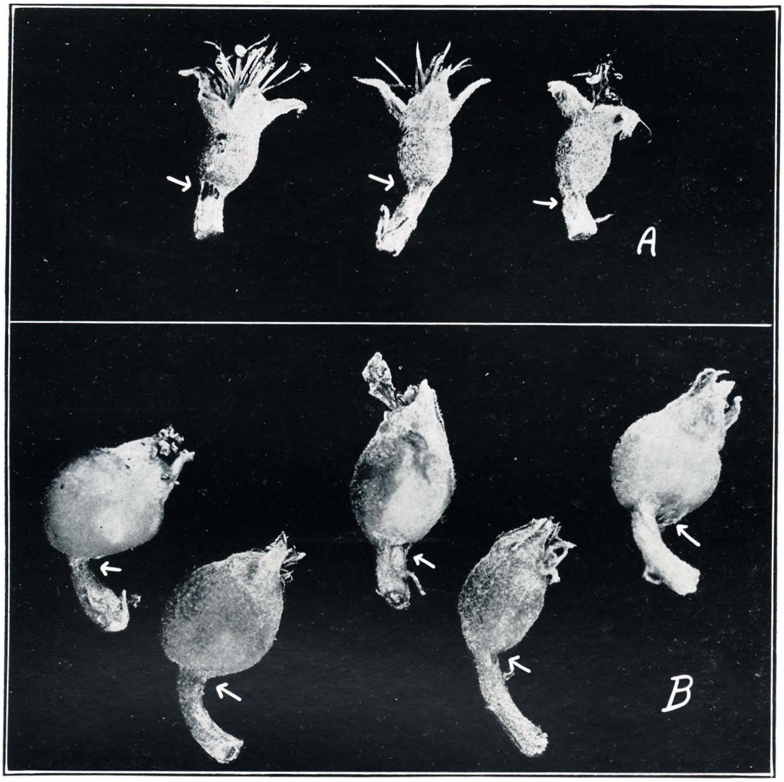

Figure 10. **Frost Injury to Fruit.** A form of frost injury that is often confused with insect and spray injury is here shown. This undoubtedly results from freezing before the blossom buds have separated in the clusters. It occurs on the upper portion of the pedicel and the adjacent lower portion of the small fruit as shown in A and later as the fruit grows it is drawn over at an acute angle toward the side where the injured area is located as shown in B.

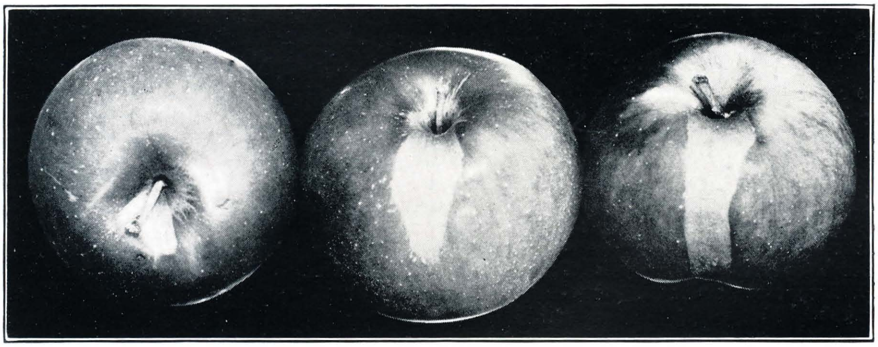

Figure 11. **Frost Injury to Fruit.** The injury illustrated in Figure 10 is responsible for the blemishes on mature apples shown here.

Figure 12. **Stunting from Lime-sulphur.** Lime-sulphur, used in the delayed dormant or prepink stages sometimes causes dwarfing of the foliage in excess of that resulting from frost injury. Here are shown the comparative effects of lime-sulphur and bordeaux when used in the delayed dormant application. A. Stayman, lime-sulphur; B. Stayman, bordeaux; C. Duchess, lime-sulphur; and D. Duchess, bordeaux. Lime-sulphur does not always produce this effect. (See Figure 13.)

Figure 13. **Stunting of Leaves.** Lime-sulphur used in the delayed dormant or prepink often does not increase dwarfing. A. Frost dwarfing on unsprayed Jonathan. B. Sprayed with lime-sulphur but without greater dwarfing.

Figure 14. **Foliage Dwarfed by Excessive Spraying.** The excessive use of lime-sulphur and lead arsenate may check growth seriously and cause heavy premature leaf-fall. A. McIntosh foliage from trees sprayed excessively. B. McIntosh foliage from trees sprayed thoroughly but not excessively. See Figure 15 also.

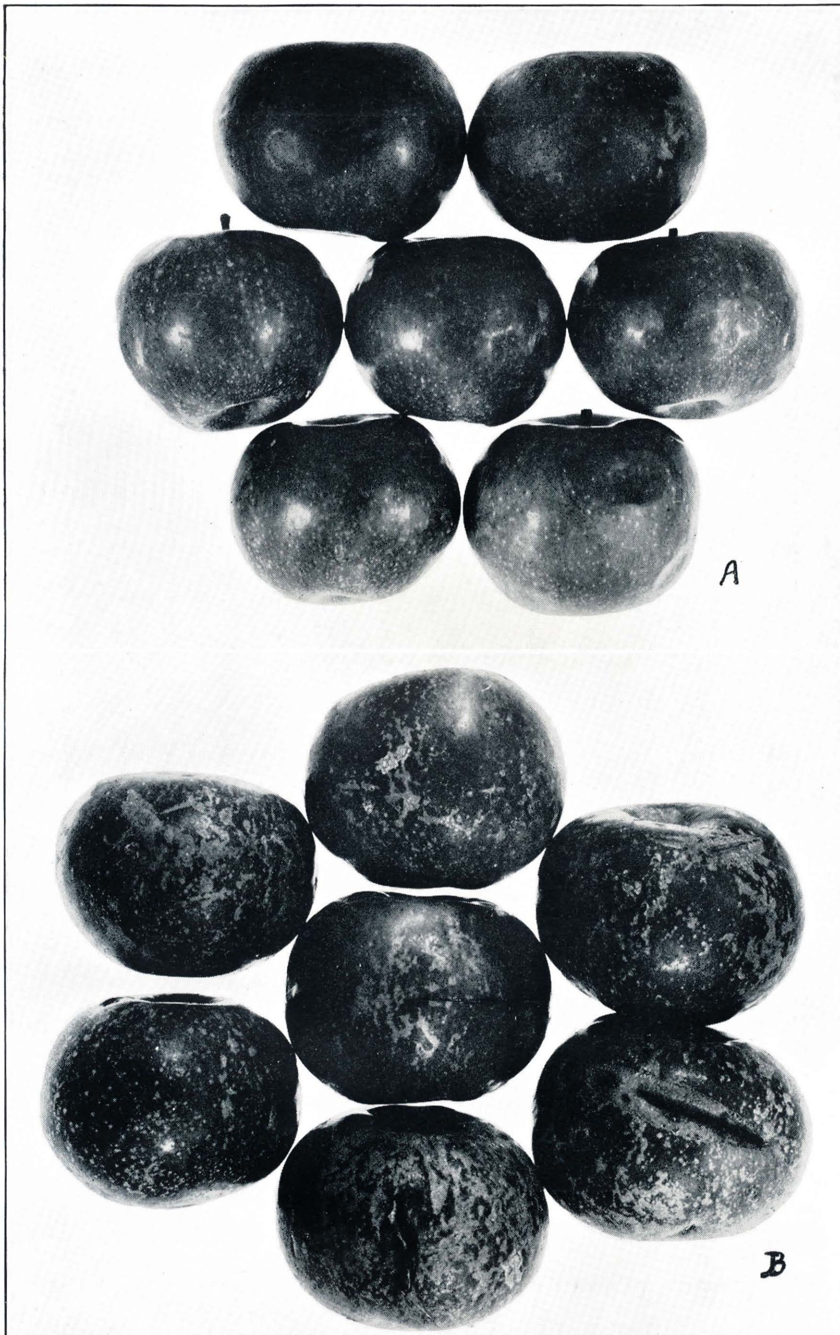

Figure 15. **Fruit Injured by Excessive Spraying.** Injury to fruit as well as to foliage may result from excessive spraying with lime-sulphur and lead arsenate. A. Fruit from normally sprayed McIntosh trees. B. Fruit from excessively sprayed trees. See Figure 14 also.

Figure 16. **Sunscald and Blossom-end Injury.** At A are shown various stages of scald. This is more severe on fruit that has been sprayed with some sulphur material. Blossom-end injury is shown in B. The third apple from bottom shows rot which often follows this injury.

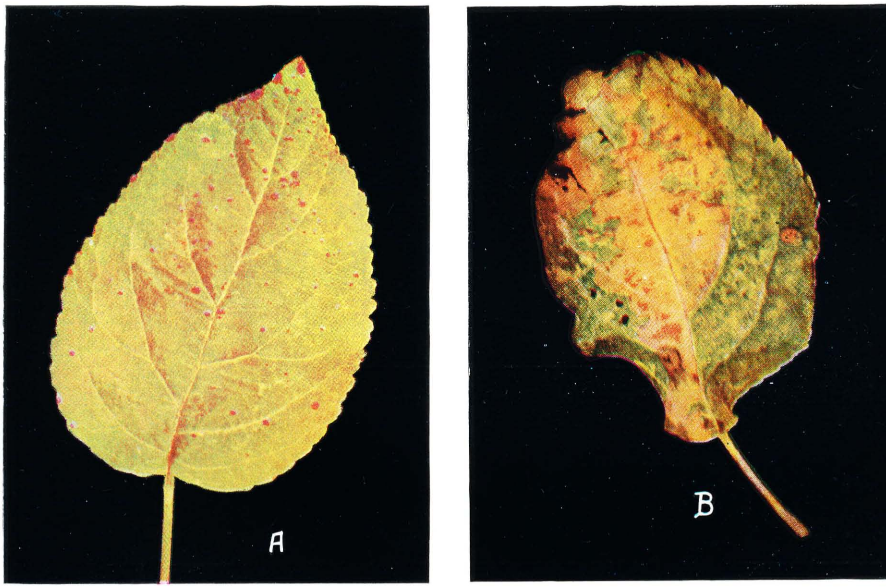

Figure 17. **Arsenical Injury.** The first stage of arsenical injury is red or purple spots as shown at A. The first stage usually seen, however, is brown spots and there may be no further development but leaves usually turn yellow, as in B and drop prematurely.

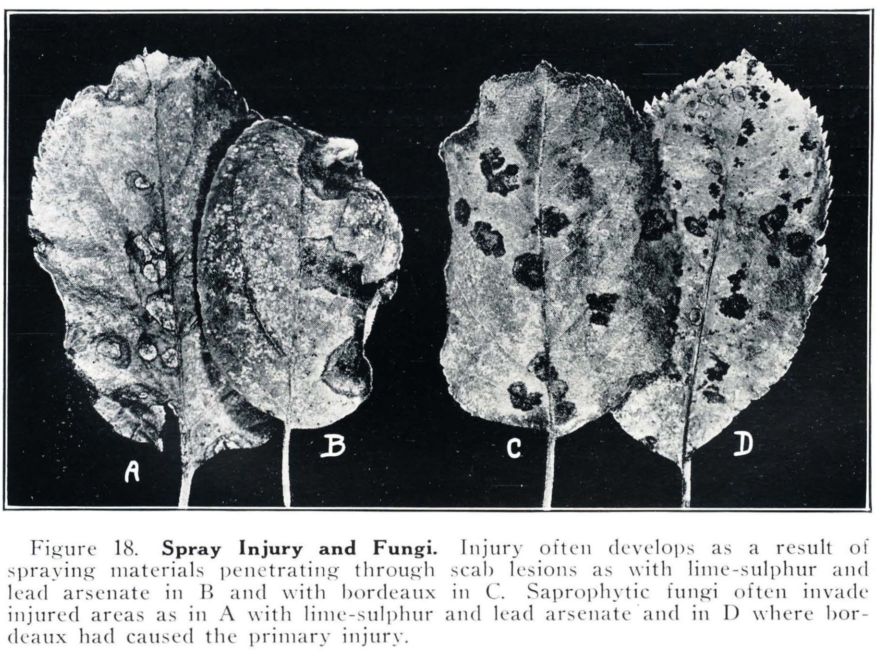

Figure 18. **Spray Injury and Fungi.** Injury often develops as a result of spraying materials penetrating through scab lesions as with lime-sulphur and lead arsenate in B and with bordeaux in C. Saprophytic fungi often invade injured areas as in A with lime-sulphur and lead arsenate and in D where bordeaux had caused the primary injury.

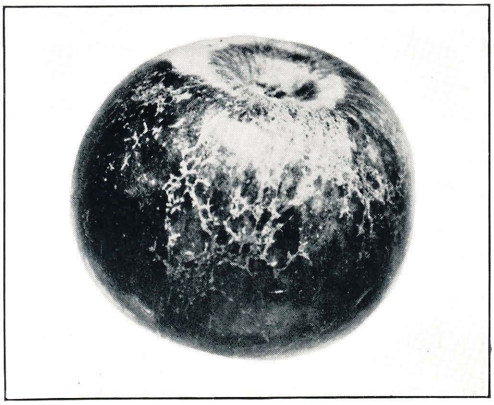

Figure 19. **Russeting by Frost.** Russeting may result from injury by frost or spraying materials. This apple has been injured by frost but lime-sulphur and lead arsenate and bordeaux cause russeting of a similar type. See Figures 20 and 21.

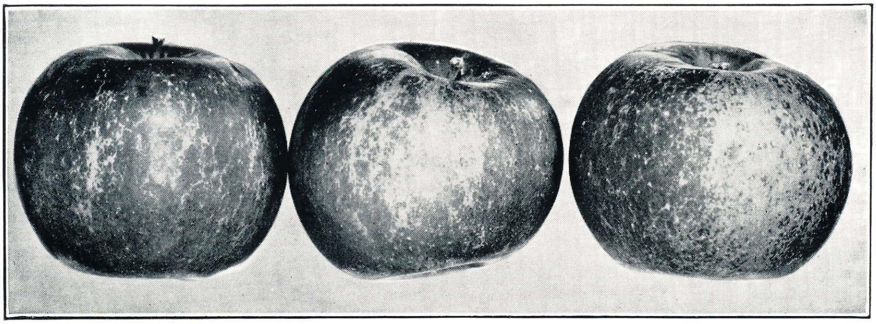

Figure 20. **Russeting by Lime-sulphur and Lead Arsenate.** Injury to the fruit in the form of russeting often follows the use of lime-sulphur and lead arsenate.

Figure 21. **Russeting by Bordeaux.** Bordeaux is very likely to cause russeting of the fruit. It may occur as a light netting of the skin or may be much more severe than shown here.

of 1.8 leaves. There were fewer leaves persistent in every instance with the high concentration. It is very clear, then, that the concentration of the lime-sulphur is an important factor in the development of foliage injury.

A comparison on Hubbardston of the two concentrations of bordeaux with light, medium, and heavy applications (Table 24, Plots 16 to 21) shows a doubtful correlation between concentration and leaf-fall. With the light application, the increase in concentration shows an increase in leaf-fall from 14 to 26 per cent; with the moderate applications, the increase in loss is from 21 to 28 per cent; but, with the heavy application, there was a decrease from 23 per cent with the weak bordeaux to 19 per cent with the strong. The variations are not large and not always in the same direction, and in no instance is the amount of leaf-fall greatly different from that on the check. With Wagener, there was slightly more leaf-fall in each case with the strong than with the weak bordeaux. It seems, therefore, that the concentration of bordeaux of the type used is of doubtful importance, within the range used in this study, in causing leaf-fall and certainly is much less important in this connection than lime-sulphur.

Rate of Application—The results with Hubbardston (Table 24) show that with the weak lime-sulphur (Plots 10, 11, and 12) each increase in dosage resulted in a corresponding increase in leaf-fall. With the light application there was a loss of 23 per cent, which was, as previously indicated, identical with that on the unsprayed tree; with the moderate application, there was a loss of 35 per cent, and, with the heavy application, the loss was increased to 41 per cent. With Wagener, 4.6 leaves per spur were persistent with the light application, 3.2 with the moderate and only 2.6 leaves with the heavy application. With the strong lime-sulphur, each increase in dosage resulted in a marked increase in leaf-fall. The percentages of loss on Hubbardston were 44, 63, and 76 per cent, respectively, for light, moderate, and heavy applications (Plots 13, 14, and 15). The results with Wagener are very comparable as the number of leaves persistent for each dosage was 2.1, 1.9, and 0.8, respectively, for the light, moderate, and heavy applications. There is, therefore, a very definite relation between the rate of application and the amount of injury that occurs from the use of lime-sulphur.

The effect of the rate of application with bordeaux is rather indefinite. With weak bordeaux on Hubbardston (Plots 16, 17 and 18), the leaf-fall was 14, 21, and 23 per cent respectively for the light, moderate, and heavy applications. With Wagener, the differences were of about the same magnitude. The results with Hubbardston with strong bordeaux (Plots 19, 20 and 21) show no definite relation between the rate of application and leaf-fall as there was less leaf-fall with the heavy application than with the light and with Wagener the results were essentially the same with all three dosages.

Amount of Active Ingredients—It has just been shown that concentration and rate of application bear a direct relation to the amount of injury resulting from lime-sulphur but that there is little or none when bordeaux is used. There is still another angle of approach which, for lime-sulphur, is probably the real determining factor. In the fifth column of Table 24 are indicated the relative amounts of actual lime-sulphur, bordeaux, and lead arsenate that were applied with each treatment. Plot 10 received a light application of weak lime-sulphur, and, since this is the smallest amount used in any plot, the value of "one" is given to the amount of active ingredients applied to these trees. Plot 11 was sprayed with the same concentration but received twice as many gallons as Plot 10; so it is obvious that two units of lime-sulphur were applied. Plot 12 received three units, Plots 13 two, and Plots 14 and 15 received four and six units respectively. The amount of injury in relation to the units of active ingredients is shown in Table 16.

Table 16.—Effect of active ingredients on leaf-fall in lime-sulphur-lead arsenate and bordeaux-lead arsenate sprays.

Materials	Concentration	Units active ingredients	Leaves persistent per spur September 30 (average)	
			Hubbardston	Wagener
Lime-sulphur and lead arsenate	Weak	1	6.1	4.6
		2	5.2	3.2
		3	4.4	2.6
	Strong	2	4.6	2.1
		4	3.0	1.9
		6	1.7	0.8
Bordeaux and lead arsenate	Weak	1	6.5	4.7
		2	5.9	4.4
		3	6.0	4.0
	Strong	3	5.8	3.8
		6	5.5	3.6
		9	6.1	3.8
Check			6.0	

These data show, with one exception, a definite relation between the amount of leaf-fall and the units of active ingredients. Similar data for bordeaux are also presented in Table 16 but show little correlation between the amount of active ingredients applied and the amount of leaf-fall occurring.

INJURIES TO FRUIT

Three types of injury by spraying materials to fruit are considered in this discussion: russeting, blossom-end injury, and scald (sun scald).

Russeting

Precise determination of the proportion of russeting attributable to spraying is difficult. Weather, vigor of the tree, and variety are factors; variation from tree to tree and from year to year and the lack of an exact standard of measurement of russeting contribute to the difficulties. Some of the inconsistencies here recorded are as yet unexplained. There are, however, rather definite indications with certain treatments. Attention will first be given to the experiments at Morrice described on page 15 in which special methods of application were employed.

Concentration—Lime-sulphur and lead arsenate (Table 24) at the high concentration caused more russeting on Hubbardston than equal dosages of weak lime-sulphur (Plot 10), 7 per cent of the fruit was lightly russeted; and, with the light application of strong lime-sulphur (Plot 13), there was 12 per cent of light russet. The moderate applications produced 12 and 27 per cent of light russet, respectively, for the weak (Plot 11) and strong (Plot 14) lime-sulphur; and, with the heavy application, the injury increased from 13 per cent of light russet with the weak material (Plot 12) to 27 per cent of light russet, 10 per cent of medium, and 1 per cent of heavy russet with the strong lime-sulphur (Plot 15). These figures show a definite relation between the amount of russeting and the concentration of the lime-sulphur and lead arsenate, though they do not show which ingredient is most important in causing that injury.

With bordeaux on Hubbardston (Table 24), the light application of weak material (Plot 16) caused 38 per cent of light, 50 per cent of medium, and 7 per cent of heavy russet, as compared to 7, 49, and 40 per cent of light, medium, and heavy russet with the light application of strong bordeaux (Plot 19). The moderate applications resulted in 26, 50, and 20 per cent of light, medium, and heavy russet respectively with weak bordeaux (Plot 17) but this was increased with the strong bordeaux (Plot 20) to 4, 33, and 62. Thus, each dosage of strong bordeaux shows russeting to a much greater degree than the same dosage of weak bordeaux.

Rate of Application—With lime-sulphur on Hubbardston (Table 24), each increase in dosage, with concentration constant, resulted in an increase in russeting. These differences were not always large. With weak lime-sulphur, the amounts of light russeting were 7, 12, and 13 per cent respectively for the light, moderate, and heavy applications (Plots 10, 11, and 12). With the strong lime-sulphur (Plots 13, 14, and 15), there was 12 per cent of light russet with the light application, and 27 per cent with the moderate application; and, with the heavy application, there was 28 per cent light, 10 per cent medium, and 1 per cent heavy russet, a significant increase in each case.

Referring again to Table 24, and comparing various dosages of the weak bordeaux, it appears that of the light, medium, and heavy russet there were, respectively, 38, 50, and 7 per cent for the light application; 26, 50, and 20 per cent for the moderate, and 12, 52, and 36 per cent for the heavy dosage (Plots 16, 17 and 18). With the strong bordeaux, the amounts of light, medium, and heavy russet, respectively, were 7, 49, and 40 per cent for the light application; 4, 33, and 62 per cent for the moderate application; and 10, 36, and 53 per cent for the heavy dosage (Plots 19, 20 and 21). In every case, except one, an increase in dosage, with concentration equal, resulted in an increase in the degree of russeting, the exception being where two treatments (moderate and heavy applications of strong bordeaux) caused russeting to an extreme degree.

Amounts of Active Ingredients—Figures showing the relation of this factor to russeting are presented in Table 17. These data show a definite relation between the amount of russeting and the units of active ingredients of lime-sulphur and lead arsenate applied. With bordeaux, the data show, with one exception, a definite increase in the degree of russet with each increase in the number of active ingredients. The exception is the one previously noted, from six to nine units, where the injury at six units was so heavy that there was little chance for an increase at nine.

Table 17.—Effect of active ingredients on russeting in Hubbardston from lime-sulphur-lead arsenate and bordeaux-lead arsenate sprays.

Materials	Concentrations	Units active ingredients	Russeting (per cent)		
			Light	Medium	Heavy
Lime-sulphur and lead arsenate	Weak	1	7	0	0
		2	12	0	0
		3	13	0	0
	Strong	2	12	0	0
		4	27	0	0
		6	28	10	1
Bordeaux and lead arsenate	Weak	1	38	50	7
		2	26	50	20
		3	12	52	36
	Strong	3	7	49	40
		6	4	33	62
		9	10	36	53

These data show (1) that russeting with both the lime-sulphur-lead arsenate spray and with bordeaux is directly proportional to concentration, the rate of application, and the amount of active ingredients; and (2) that bordeaux in the smallest amounts may be expected to cause more russeting than even excessive amounts of lime-sulphur and lead arsenate. In the succeeding paragraphs, there will be presented data concerning the effect of normal applications of lime-sulphur, lead arsenate, bordeaux, and other materials on the development of russet.

Lime-sulphur and Lead Arsenate—The effect on russeting of the use of lime-sulphur, 2½ gallons, and lead arsenate, 2 or 3 pounds in 100, is shown in nearly every table in the appendix and the results with this combination are taken as a standard with which to compare other treatments. These data are presented in Table 23, Plot 1; Table 25, Plots 2 and 8; Table 26, Plots 2 and 9; Table 28, Plots 3 and 11; Table 29, Plots 2 and 8; Table 30, Plot 9; Table 31, Plot 3; Table 32, Plot 4; Table 33, Plot 3; Table 34, Plot 3; Table 36, Plot 6, and Table 37, Plot 1. A summarized tabular statement of the increase in the percentage of fruit russeted above that occurring on unsprayed trees is shown in Table 18.

These data show an increase in russeting from lime-sulphur and lead arsenate in nearly every instance. The variations from year to year and between varieties in one year are noticeable. No explanation of these variations is offered. There is definite indication, however, that this spray is very likely to cause some light russeting and occasionally severe injury.

Lime With Lime-sulphur and Lead Arsenate—Hydrated or quick lime was added in several cases to the lime-sulphur lead arsenate spray. The results are shown in Table 23, Plot 3; Table 25, Plot 4; Table 26, Plot 4; Table 28, Plots 1 and 2; Table 31, Plot 4; Table 32, Plot 5, and Table 34, Plots 7 and 8. These data are summarized in Table 19.

Table 18.—Russeting from lime-sulphur and lead arsenate.

Year	Increase in light russet (per cent) from lime-sulphur and lead arsenate over that on unsprayed trees				
	Hubbardston	Jonathan	McIntosh	Stayman	Grimes
1924	12				
1925	10.9*	0	5.9		
1926	2.3*	34.0 and 11.6†	8.7		
1927	0*	2.5	6.9		
1928	−14.7*	19.3 and 10.0†	37.1 and 8.6†	31, 40 and 13‡	7 and —8†
1929		25.3 and 1.7†			
1930		11.7			

*Average of two plots.
†The second figure is medium russeting and there was in a few instances a small amount of heavy russet also.
‡Light, medium and heavy russet.

The addition of lime to the lime-sulphur and lead arsenate spray reduced the amount of russeting. None is recorded for either treatment in 1925 with Jonathan. The reduction was small in some instances but was marked in others, and the general appearance of the fruit was probably improved to a greater extent than is indicated by the percentage differences.

Table 19.—The effect on russet of lime in the lime-sulphur-lead arsenate spray.

Year	Decrease (per cent) in light russeting resulting from lime-sulphur, lead arsenate and lime from that caused by lime-sulphur and lead arsenate without lime		
	Hubbardston	Jonathan	McIntosh
1924	8.0		
1925	2.5	0*	3.7
1926	4.3	18.2 and 10.2†	5.5
1928	8.0, 1.9 and 1.3‡	....	23.7

*No russet occured with either spray.
†Light and medium russet.
‡Light, medium and heavy russet.

Casein Spreader with Lime-sulphur and Lead Arsenate—Results from the use of casein spreader with lime-sulphur and lead arsenate are shown in Table 23, Plot 2; Table 25, Plot 3; Table 26, Plot 3; Table 29, Plot 3 (this is with iron sulphate and should also be compared with Plot 4); Table 30, Plot 1 (this is also with iron sulphate and should be compared with Plot 6); Table 31, Plot 2; and Table 32, Plot 3. These data are summarized in Table 20.

Table 20.—The effect on russet of casein spreader in the lime-sulphur-lead arsenate spray.

Year	Increase (per cent) in light russeting resulting from lime-sulphur, lead arsenate and casein spreader over that caused by lime-sulphur and lead arsenate without casein spreader		
	Hubbardston	Jonathan	McIntosh
1924	12 and 7*		
1925	0.3	0	13.7
1926	5.4	0	−4.4
1929		2.3	
1930		12.5	

*Light and heavy russet.

They show no essential differences in three instances but do show a decrease in russeting with casein spreader in one instance and increases in four cases, two of which are large. The results are apparently irregular but some factor evidently affects the combination of materials so that, under some conditions, the addition of casein spreader causes a marked increase in the amount of russeting.

Iron Sulphate—The addition of iron sulphate to lime-sulphur and lead arsenate has, in some instances, resulted in a marked reduction in russeting; in some cases, there was no russeting with either combination, in others, there was no difference but in still others there was a slight increase with the iron sulphate. The general indication is that there is slightly less russeting when iron sulphate is added but, because of the large error involved in classifying russet, it is hazardous to attempt a definite conclusion.

Dry Lime-sulphur—Several comparisons of dry and liquid lime-sulphur were made in the course of these experiments. The results are shown in Table 25, Plot 7; Table 26, Plots 11, 12, and 13; Table 29, Plot 7; Table 30, Plots 13 and 14; Table 32, Plots 8 and 9; and Table 33, Plots 7 and 8. At Morrice, with dry lime-sulphur A, the results are extremely variable, probably indicating that these differences are not significant or that Hubbardston is not a good variety for such studies unless the differences are marked. With Jonathan, the same material gave better results in the two seasons, for which results are available, than the equivalent of liquid lime-sulphur.

At Belding, in 1926 and 1927, where records are available on McIntosh for dry lime-sulphurs A and B, there was distinctly less russeting with liquid lime-sulphur than with either of the dry materials and there was less russeting with A than with B. These figures, which compare the two kinds of dry lime-sulphur, are supported by data obtained in another orchard at Belding in 1930 on McIntosh. The results of this experiment are not reported here in detail but may be summarized to the effect that there was practically no russet with liquid lime-sulphur or dry lime-sulphur A but considerable netting of the skin with dry lime-sulphur B. In 1926 and 1927, the injury with the dry lime-sulphur was manifested chiefly in the form of conspicuous roughening of the lenticels rather than a definite russet. With Jonathan at Morrice, there was probably a greater difference in the appearance of the fruit than is indicated by the percentage differences in russeting.

Wettable Sulphur and Dry-mix—At Morrice, in 1924, with Hubbardston (Table 23), the use of dry-mix (Plots 4 and 5) resulted in 12 and 7 per cent of light russet as compared to 13 per cent with lime-sulphur (Plot 1). In 1926 (Table 26), the results were the same with Hubbardston, (Plots 1 and 2) but with Jonathan there was 4 per cent of light russet with wettable sulphur while with lime-sulphur there was 26.3 per cent of light russet and 4.8 per cent of medium russet. In 1927 (Table 27), no russeting was recorded with either material on Hubbardston. With Jonathan, no russet counts were made with the wettable sulphur used on Plots 11 and 12 but the finish and general appearance of the fruits was much better than in other plots, though scab control was very unsatisfactory. At Belding, in 1927 (Table 33), there was somewhat less russeting in the dry-mix plot (Plot 2) than with lime-sulphur (Plot 3). The use of dry-mix was not started, however, until the two-weeks application and a greater difference might have prevailed if dry-mix had been used in the petal-fall spray. The conclusion based on the results of these experiments and on observations made in commercially sprayed orchards, is that the finish of the fruit from trees sprayed with dry-mix sulphur-lime or wettable sulphur is usually superior to that of fruit from lime-sulphur sprayed trees. Scab control, however, is a limiting factor in the use of these materials.

Flotation Sulphur—Koppers flotation sulphur was used at Morrice in 1930 (Table 30, Plot 3). On Jonathan, there was 3.2 per cent of light russet as compared to 12.9 per cent with lime-sulphur (Plot 9) and the difference in the appearance of the fruit was greater than is indicated by these figures. The value of this material for scab control, under Michigan conditions, has not been established.

Bordeaux—The principal limiting factor in the use of bordeaux for all summer applications on apples in Michigan is the russeting that follows its use. Ample evidence to support this statement is found in the data presented in Table 23, Plot 8; Table 25, Plot 9; Table 26, Plot 10; Table 27, Plot 10; Table 28, Plot 12; Table 29, Plot 9; Table 30, Plot 10; Table 31, Plot 1; Table 32, Plots 1 and 2; Table 33, Plot 1; Table 34, Plot 1, and Table 36, Plot 5. There is almost invariably a large increase in russeting over that found where lime-sulphur and lead arsenate were used. This statement refers to the use of bordeaux for all applications or for all except the petal-fall when a lime-sulphur spray was sometimes substituted. Bordeaux has been used repeatedly in the second-brood application when some lime-sulphur spray has been applied in all previous applications. No russeting has been observed to result from such use. The use of bordeaux in the pre-pink or delayed dormant application would be desirable to reduce certain types of foliage injury but this practice cannot be recommended unqualifiedly because slight russeting develops in some seasons although excellent results have been obtained in other years. One instance of this is shown in Table 37, Plot 4, with Duchess and Grimes. There is one variety that is significantly less susceptible to russeting from bordeaux than others. Northern Spy, as observed in commercial work and in the one instance that it was studied in these experiments, has been found to be much less subject to russet than any other variety observed. In Table 29, Plot 9, Spy shows 10.3 per cent of light russet from the use of 2-2-100 bordeaux in all applications except the petal-fall. With Baldwin, the injury was increased to 37.2 and

Table 21.—Blossom-end injury on Jonathan apples.

Materials with which lead arsenate was combined	Amount in 100 gal.	Apples with blossom-end injury (per cent)					
		1925	1926	1927	1928	1929	1930
Lime-sulphur	2½ gal.	3.1–4.7*	6.2–7.5*	0–0*	0.6–4.9*	6.6–8.2*	0.8
Lime-sulphur Quick lime	2½ gal. 5 lbs.	0.8	8.8		0.7		
Lime-sulphur Casein spreader	2½ gal. 1 lb.	2.0	9.0				
Lime-sulphur Cane sugar	2½ gal. 5 oz.	6.7					
Lime-sulphur Iron sulphate	2½ gal. 1¼ lbs.	0	2.7	0	0	1.0–0.2–0*	0.9–0.4–0.3–0.9*
Dry lime-sulphur A	8–10 lbs.	4.7	11.1			6.1	11.6
Bordeaux	2-2-100 and 3-3-100	0	0		0.8–0.3†	0	0
Sulfocide Casein spreader	2/3 gal. 3 lbs.	11.3					
Kopper's flotation sulphur	16 lbs.						10.4
Calcium sulphide (Cal-Mo-Sul)	12½ lbs.						2.1
Check		0	1.4‡	0	0	0	0.2‡

*Each figure is from a different plot.
†A lime-sulphur spray was used in the petal-fall application.
‡This injury was unquestionably caused by something other than spraying material, but was such that it could not be definitely distinguished from true blossom-end injury.

9.0 per cent of light and medium russeting, and with Jonathan to 42.8, 18.0 and 2.9 per cent respectively of light, medium, and heavy russet. It is true also that there was much less russet on Spy with lime-sulphur (Plot 8) than on Baldwin and Jonathan.

Other Copper Sprays—Basic copper sulphate and copper carbonate were used as shown in Table 36, Plots 1, 2, 3 and 4. Compared with bordeaux (Plot 5) there is with Stayman a definite increase with all special materials. There is less of light russeting, but decidedly more of heavy russet. With Grimes, the results are not so greatly different from bordeaux but there is still too much.

Blossom-end Injury

Blossom-end injury, which has been described on page 12 has not been observed on many varieties. Records are available in this work for Jonathan only. It has been found, however, on Northern Spy, Winter Banana, Ben Davis, Gano and other varieties. There is a definite relation between the presence and amount of this injury and the material with which lead arsenate is combined. Data for Jonathan which are presented in Tables 25, 26, 27, 28, 29, and 30, and are summarized in Table 21 show definite trends. When lead arsenate (2-3 lbs. in 100 gallons) was used with liquid lime-sulphur (2½ gallons in 100) or dry lime-sulphur A (8-10 lbs. in 100 gallons), considerable blossom-end injury developed (see Table 21). The addition of lime improved results in some instances, but not always. The presence of casein spreader had no significant effect. Cane sugar, with lime sulphur and lead arsenate, did not prevent the injury. The addition of iron sulphate reduced this injury significantly. Bordeaux and lead arsenate caused practically none of this type of injury. With Sulfocide it was severe, with Koppers flotation sulphur there was some and with calcium sulphide there was a small amount. The two outstanding combinations in the elimination of this trouble on Jonathan are (1) bordeaux and lead arsenate and (2) lime-sulphur, iron sulphate and lead arsenate.

The relation of the concentration of the lime-sulphur and lead arsenate to this injury is not established in this work. In Table 26, Plots 6, 7, 8, and 9, there are four variations and with the results shown in Table 22, and a

Table 22.—Blossom-end injury on Jonathan.

Plot	Materials	Amount in 100 gal.	Apples with blossom-end injury (per cent)
9	Lime-sulphur Lead arsenate	2½ gal. 2 lbs.	7.5
8	Lime-sulphur Lead arsenate	2½ gal. 1 lb.	5.4
7	Lime sulphur Lead arsenate	1¼ gal. 1 lb.	2.2
6	Lime-sulphur Lead arsenate	1¼ gal. none	1.1

lessening of injury with each reduction in concentration of either material is indicated. Other data, apparently contradictory, follow.

In the same experiment (Table 26, Plots 11, 12 and 13), dry lime-sulphur A was used at three concentrations, six, eight, and ten pounds in 100 gallons with 10.1, 6.9 and 11.1 per cent of blossom-end injury respectively for the three concentrations of dry lime-sulphur. Lead arsenate was used uniformly with all at two pounds in 100 gallons. There is no correlation here between concentration and injury. In 1928 (Table 28, Plots 8, 9, 10, and 11), lime-sulphur was used in the after-blossom applications at four concentrations; one, one and one-half, two, and two and one-half gallons in 100 gallons. The lead arsenate was uniform in all, with three pounds in the petal-fall and two-weeks applications and two pounds in the second brood spray. The amounts of injury were 4.9, 18.7, 6.1, and 3.8 per cent respectively for the four concentrations of lime-sulphur, and again there is no correlation. In 1930 (Table 30, Plots 9, 12, 13 and 14), with lead arsenate uniform in all plots lime-sulphur was used at two concentrations, one gallon and two and one-half gallons in 100, and dry lime-sulphur A at two concentrations, four and ten pounds in 100 gallons. The results with the liquid lime-sulphur were 23.9 per cent and 0.8 per cent respectively for the one gallon and two and one-half gallons. There was 26.7 per cent injury with four pounds of dry lime-sulphur and 11.6 per cent with 10 pounds. The injury with the low concentrations of liquid and dry lime-sulphur not only affected a higher percentage of the fruit but the injury on each apple was much worse than with the high concentration of each kind of lime-sulphur. This greater severity of injury with the low concentration may have been due to a greater development of rot, although this phase of the problem was not studied. These results with regard to concentration of lime-sulphur and the development of blossom-end injury, obviously, are not conclusive although the most severe injury observed was with low concentrations of liquid and dry lime-sulphur.

Sunscald—A limited amount of data concerning the relation of spraying materials to the development of sunscald is available. The data are presented in Table 30. The latter part of the summer in 1930 was very favorable to this sort of injury and it was seen in practically all plots, sprayed and unsprayed, but there were marked differences in the amounts under various treatments. The plots that were sprayed with sulphur preparations in the second-brood application showed more than those that were unsprayed or were sprayed with bordeaux at that time. The samples from which the counts were made were not taken in such a way as to show the full development of this injury but give a general comparison. Of the unsprayed fruit, 0.7 per cent were affected; for the plots sprayed with bordeaux in the last application, 0.9, 0.4, 0.3, 0.9, 0.2, 0.8, 0.3, 0 per cent; for Koppers flotation sulphur, 2.0 per cent; for calcium sulphide, 2.1 per cent; for lime-sulphur (2½ gallons in 100) 2.6 and lime-sulphur (1 gallon in 100) 0.4 per cent and for dry lime-sulphur (10 pounds in 100 gallons) 1.4 and dry lime-sulphur (4 pounds in 100 gallons) 2.0 per cent. These figures show definitely less with bordeaux but the figures for the worst plots where sulphur sprays were used do not show the full extent of injury there.

SUMMARY

Types of Injury

Lime-sulphur, alone or in combination with lead arsenate, may cause definite and almost immediate injury that is called lime-sulphur burn. This is characterized by brown leaf tissue in small or large areas. High temperature favors the development of this injury and is probably one of the most important determining factors but injury does not always occur when the temperature is high and may occur when the temperature is low. High humidity and slow drying at high or low temperatures favor injury but low humidity and rapid drying are unfavorable to injury even though the temperature is high. Tender foliage is more susceptible to injury than mature, hardened foliage. High concentrations of lime-sulphur cause more injury than low concentrations, other factors being equal. Heavy application is likewise likely to increase injury and the presence of oil in lime-sulphur may result in more injury than would result from lime-sulphur alone.

Distortion of leaves often results from marginal injury by lime-sulphur when the leaves are partly grown.

Stunting and blistering of the leaves that appear with the blossom buds often occur as the result of frost injury. This is sometimes increased by lime-sulphur. Stunting and generally retarded leaf development may result from the excessive use of lime-sulphur and lead arsenate during the period when the leaves are developing.

Lime-sulphur injury often occurs through deep seated scab lesions on the leaves. This kills the scab but may cause the leaves to drop.

Sun scald on the fruit may occur with any spraying treatment but its development seems to be accentuated by the presence of sulphur in any form.

Dry lime-sulphur may cause all the effects observed to follow the use of liquid lime-sulphur but when used at equivalent concentrations (four pounds of dry for one gallon of liquid) there is usually slightly less injury with the dry lime-sulphur. There are differences, however, between different brands of dry lime-sulphur.

Free sulphur sprays such as dry-mix, wettable sulphur, flotation sulphur, etc., have not been observed to have caused any direct injury to foliage. Calcium monosulphide (Cal-Mo-Sul) has not caused injury to the foliage of the apple.

Yellow-leaf injury often follows the use of lime-sulphur and acid lead arsenate and is believed to result from the water soluble arsenic formed when these materials are combined. This injury is sometimes seen in the initial stage as purple or reddish spots, but the first stage usually observed is small or large brown spots that may or may not be followed by yellowing of the leaves. Leaves drop soon after turning yellow. Yellow leaves may appear within a week to ten days after an application but the appearance may be delayed longer than that.

Much of the russeting of the fruit following the use of lime-sulphur and lead arsenate is probably the result of injury from water soluble arsenic. The role of lime-sulphur in this connection is not fully established although lime-sulphur alone causes practically no russeting. Frost injury often causes russeting that is indistinguishable from russeting caused by spraying materials.

Blossom-end injury is caused by soluble arsenic in lime-sulphur-lead arsenate sprays and with lead arsenate in other combinations.

Bordeaux sometimes causes injury to the foliage of the apple. This injury is evident first as purple spots which turn brown and the leaf may become yellow and drop. This injury usually is not of consequence on apples in Michigan. The russeting of the fruit, following the use of bordeaux in early summer applications, is a limiting factor in the use of this spray on apples. Bordeaux applied late in the season has not caused russeting.

Amounts of Injury to Foliage and Fruit

Lime-sulphur, used alone, may under some conditions cause true lime-sulphur burn. Leaves so injured may or may not drop prematurely but even when this injury does not occur there is often slightly greater premature leaf-fall than from check trees. This injury is less with low concentrations of lime-sulphur. Lime-sulphur without lead arsenate causes very little or no russeting of the fruit.

The use of lime-sulphur (2½ gallons in 100) and lead arsenate (2 to 3 pounds) in mid- and late-summer often causes serious loss of leaves as a result of arsenical injury. The loss may be 40 to 50 per cent or more of the leaves on spurs. Wagener is very susceptible and McIntosh very resistant to this yellow-leaf injury. The leaves that persist are often injured so that their functioning is undoubtedly impaired. This spray also often causes considerable russeting of the fruit and on susceptible varieties, blossom-end injury. The applications most responsible for russeting of the fruit have not been determined but the petal-fall and other early season applications are probably important.

Lowering the concentration of the lime-sulphur but not of the lead arsenate usually reduces foliage injury on most varieties but there are exceptions to this. The effect of lowered concentration on russeting is not clear, but, in most instances, the general appearance of the fruit from these plots has been much better than with the higher concentrations. Blossom-end injury has not been consistently reduced but has actually been greater in some instances with low concentrations.

The addition of lime to the standard concentration of lime-sulphur (2½ gallons in 100) with lead arsenate has not reduced or increased foliage injury but has reduced the amount of russeting. The effect of lime on blossom-end injury is not well established.

Casein spreader has not decreased foliage injury but has increased it in several instances. Russeting has been greater in several cases and blossom-end injury has not been prevented.

The addition of cane sugar, calcium sulphate, or ground tobacco has not caused significant differences in foliage injury, russeting, or blossom-end injury.

Aluminum sulphate has not prevented yellow-leaf injury.

Iron sulphate in the so-called standard lime-sulphur-lead arsenate spray has reduced yellow-leaf injury remarkably, but does not prevent true lime-sulphur burn unless used in large quantities. Russeting is probably reduced to a certain extent and blossom-end injury is practically prevented.

Dry lime-sulphur has caused about the same amount of leaf-fall as comparable amounts fungicidally of liquid lime-sulphur, but comparisons of persistent leaves have often indicated a slightly better condition where the dry lime-sulphur had been used. One gallon of liquid lime-sulphur is considered to be equal to at least four pounds of dry lime-sulphur in the control of apple scab. Russeting on Jonathan has been less with dry lime-sulphur than with an equivalent of liquid lime-sulphur, but with McIntosh there has been more russeting with the dry lime-sulphurs and there have also been consistent differences between two brands of dry lime-sulphur. Blossom-end injury seems to be just as great with the dry as with the liquid lime-sulphur.

Dry-mix, wettable sulphurs, and other free sulphur materials in combination with lead arsenate are unlikely to cause injury to foliage, especially if lime is present in the mixture. The finish of the fruit is usually excellent where they are used and blossom-end injury usually is not so serious as when lime-sulphur and lead arsenate are used. A limiting factor in the use of these materials is their relatively low fungicidal value in the control of apple scab.

Flotation sulphur has not been observed to cause any foliage injury or russeting of the fruit, but considerable blossom-end injury developed in Jonathan when this sulphur was used with lead arsenate. Calcium monosulphide has not been observed to cause any injury to apple foliage or fruit. The value of these materials to control scab has not been established in Michigan.

Bordeaux causes very little foliage injury on the apple under Michigan conditions, in fact, bordeaux sprayed trees are usually characterized by excellent foliage. Blossom-end injury has not been observed on bordeaux sprayed trees, but the all-season use of bordeaux is undesirable on most varieties because large amounts of russeting usually develop from early summer applications. Bordeaux, however, can be used very advantageously in the late summer application as russeting is unlikely to occur at that time and there is little or no hazard to foliage when spraying with bordeaux is done in periods of high temperature.

Other copper sprays, such as basic copper sulphate and copper carbonate, have caused severe injury to both fruit and foliage.

One experiment in which special methods of applications were used showed definitely with lime-sulphur and lead arsenate that injury to foliage and russeting of the fruit are directly proportional to concentration, rate of application, and the actual amount of active ingredients applied. With bordeaux and lead arsenate, there was little or no correlation between leaf-fall and any of the factors mentioned, but russeting of the fruit was very definitely correlated with concentration, rate of application, and the amounts of copper applied.

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Table 23.—Experiments at Morrice, 1924.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)						Russet on fruit (per cent)	
			Hubbardston					Wagener	Hubbardston	
			Original	June 30	August 5	September 3	September 30	September 30	Light	Medium
1..........	Lime-sulphur*....................................	2½ gal.	7.9	6.3	6.3	4.5	4.5	2.6	13	0
2..........	Lime-sulphur*.................................... Casein spreader....................................	2½ gal. 1 lb.	7.9	6.1	6.1	3.6	3.5	1.4	25	7
3..........	Lime-sulphur*.................................... Quick lime....................................	2½ gal. 10 lbs.	7.6	5.9	5.9	4.1	3.9	....	5	0
4..........	Dry-mix*....................................	25 lbs.	7.8	5.7	5.7	5.5	5.4	....	12	0
5..........	Lime-sulphur* (prepink and pink applications)........ Dry-mix* (petal-fall, two weeks and second-brood applications)....................................	2½ gal. 25 lbs.	7.9	6.2	6.2	5.9	5.9	....	7	0
6..........	Colloidal sulphur I*....................................	10 lbs.	7.8	6.4	6.4	5.4	5.3	....	3	0
7..........	Colloidal sulphur II*....................................	½ gal.	7.5	6.4	6.4	5.7	5.5	....	14	0
8..........	Bordeaux* (average of six plots shown in Table 24)....	....	7.6	6.7	5.9	5.9	5.8	4.0	....	....
9..........	Check....................................	....	7.8	6.3	6.3	6.2	6.0	....	1	0

*Lead arsenate was used, unless otherwise indicated, at the rate of 2 lbs. in each 100 gallons of spray in the pink and all succeeding applications.

Table 24.—Experiments at Morrice, 1924.

Plot	Materials	Amount in 100 gal.	Rate of application	Relative amounts active ingredients	Leaves on spurs (average)						Russet on fruit (per cent)		
					Hubbardston					Wagener	Hubbardston		
					June 1	June 30	August 5	September 3	September 30	September 30	Light	Medium	Heavy
9....	Check............	....	....	....	7.8	6.3	6.3	6.2	6.0	....	1	0	0
10....	Lime-sulphur..... Lead arsenate.....	1½ gal. 1½ lbs.	Light	1	7.9	6.6	6.6	6.2	6.1	4.6	7	0	0
11....	Lime-sulphur..... Lead arsenate.....	1½ gal. 1½ lbs.	Moderate	2	8.0	6.1	6.1	5.2	5.2	3.2	12	0	0
12....	Lime-sulphur..... Lead arsenate.....	1½ gal. 1½ lbs.	Heavy	3	8.2	5.7	5.7	4.4	4.4	2.6	13	0	0
13....	Lime-sulphur..... Lead arsenate.....	3 gal. 3 lbs.	Light	2	8.2	6.2	6.2	4.8	4.6	2.1	12	0	0
14....	Lime-sulphur..... Lead arsenate.....	3 gal. 3 lbs.	Moderate	4	8.1	5.7	5.7	3.3	3.0	1.9	27	0	0
15....	Lime-sulphur..... Lead arsenate.....	3 gal. 3 lbs.	Heavy	6	7.3	5.0	5.0	1.9	1.7	0.8	28	10	1
16....	Bordeaux......... Lead arsenate.....	2–4–100 1 lb.	Light	1	7.6	7.1	6.7	6.6	6.5	4.7	38	50	7
17....	Bordeaux......... Lead arsenate.....	2–4–100 1 lb.	Moderate	2	7.5	6.6	6.1	6.1	5.9	4.4	26	50	20
18....	Bordeaux......... Lead arsenate.....	2–4–100 1 lb.	Heavy	3	7.8	6.8	6.1	6.1	6.0	4.0	12	52	36
19....	Bordeaux......... Lead arsenate.....	6–12–100 3 lbs.	Light..	3	7.9	6.8	5.8	5.8	5.8	3.8	7	49	40
20....	Bordeaux......... Lead arsenate.....	6–12–100 3 lbs.	Moderate	6	7.7	6.6	5.6	5.6	5.5	3.6	4	33	62
21....	Bordeaux......... Lead arsenate.....	6–12–100 3 lbs.	Heavy	9	7.6	6.7	6.1	6.1	6.1	3.8	10	36	53

Table 25.—Experiments at Morrice, 1925.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)										Injury to fruit (per cent)			
			Jonathan					Hubbardston					Hubbardston		Jonathan	
			Original	June 18	July 25	Aug. 18	Sept. 10	Original	June 20	Aug. 1	Aug. 17	Sept. 9	Light Russet	Medium Russet	Light Russet	Blossom-end injury
1..........	Sulfocide*.................... Casein spreader...............	2/3 gal. 3 lbs.	7.7	6.4	6.0	4.3	3.2	6.8	5.7	5.5	5.0	4.7	22.9	0	0	11.3
2..........	Lime-sulphur*................	2½ gal.	7.5	6.4	6.1	4.7	3.9	7.2	6.4	6.1	5.1	4.9	21.3	0	0	3.1
3..........	Lime-sulphur*................ Casein spreader...............	2½ gal. 1 lb.	7.9	7.2	6.8	5.5	4.7	6.3	5.6	5.5	4.8	4.6	19.1	0	0	2.0
4..........	Lime-sulphur*................ Quick lime....................	2½ gal. 5 lbs.	7.7	7.1	6.9	5.9	5.4	7.2	5.7	5.5	4.9	4.8	18.8	0	0	0.8
5..........	Lime-sulphur*................ Iron sulphate.................	2½ gal. 1¼ lbs.	7.8	7.6	7.5	7.4	7.2	7.1	6.1	6.1	5.9	5.8	17.1	0	0	0
6..........	Lime-sulphur*................ Cane sugar...................	2½ gal. 5 oz.	7.8	7.3	7.1	6.2	6.1	7.1	6.0	5.9	5.5	5.4	19.9	0	0	6.7
7..........	Dry lime-sulphur A*...........	8 lbs.	7.6	7.3	7.1	6.1	5.2	6.7	6.2	6.2	5.8	5.0	25.3	0	0	4.7
8..........	Lime-sulphur* (same as Plot 2)..	2½ gal.	7.6	7.3	7.2	6.0	5.3	7.2	6.0	5.9	5.1	4.8	16.4	0	0	4.7
9..........	Bordeaux†*..................	4-8-100	8.1	8.1	8.0	8.0	7.7	7.3	6.7	6.6	6.5	6.5	72.6	8.5	24.4	0
10..........	Check.......................	....	7.6	7.5	7.4	7.4	7.4	7.0	6.7	6.7	6.5	6.5	7.9	0	0	0

*Lead arsenate was used, unless otherwise indicated, at the rate of 2 lbs. in each 100 gallons of spray in the pink and all later applications.
†Quick lime was used in making this bordeaux.

Table 26.—Experiments at Morrice, 1926.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)								Injury to fruit (per cent)				
			Jonathan				Hubbardston				Hubbardston		Jonathan		Blossom-end injury
			June 4-5	June 28	Aug. 5	Sept. 13	June 12	June 28	Aug. 5	Sept. 14	Light Russet	Medium Russet	Light Russet	Medium Russet	
1..........	Lime-sulphur (pre-blossom and calyx applications)*................... Wettable sulphur (2 weeks and second brood applications)..................	2½ gal. 10 lbs.	7.2	7.1	7.0	5.9	6.8	6.9	6.9	6.4	10.8	0	4.8	0	2.4
2..........	Lime-sulphur*........................	2½ gal.	7.0	6.8	6.3	4.8	6.8	5.9	5.6	4.6	10.9	1.0	26.3	4.8	6.2
3..........	Lime-sulphur*........................ Casein spreader........................	2½ gal. 1 lb.	6.6	6.6	6.5	4.6	7.1	6.2	5.6	4.0	16.3	0.1	34.0	9.0	9.0
4..........	Lime-sulphur*........................ Quick lime........................	2½ gal. 5 lbs.	6.5	6.4	6.2	5.0	7.1	6.4	6.1	4.5	6.6	0	15.8	1.4	8.8
5..........	Lime-sulphur*........................ Iron sulphate........................	2½ gal. 1¼ lbs.	6.8	6.7	6.9	5.9	7.0	6.4	6.1	5.4	12.7	0.1	18.0	0.5	2.7
6..........	Lime-sulphur........................ Lead arsenate........................	1¼ gal. none	6.9	6.9	6.9	6.3	7.2	6.8	6.7	6.2	10.0	0	16.4	0.2	1.1
7..........	Lime-sulphur........................ Lead arsenate........................	1¼ gal. 1 lb.	7.0	7.2	6.8	5.8	7.3	7.0	7.0	6.4	0	0	11.4	0.7	2.2
8..........	Lime-sulphur........................ Lead arsenate........................	2½ gal. 1 lb.	7.7	6.8	6.6	5.3	6.9	6.7	6.3	4.6	15.0	0.1	32.4	0.6	5.4
9..........	Lime-sulphur........................ Lead arsenate........................	2½ gal. 2 lbs.	6.6	6.3	6.2	5.2	7.1	6.4	5.8	4.6	10.8	0.2	41.7	18.5	7.5
10..........	Bordeaux*—†........................	2-2-100	7.1	6.8	7.3	6.6	6.9	6.7	7.1	6.9	56.1	10.6	58.3	8.0	0
11..........	Dry lime-sulphur A*..................	10 lbs.	6.9	6.7	6.5	5.1	6.8	6.5	5.2	5.0	14.7	0.7	37.4	1.4	11.1
12..........	Dry lime-sulphur A*..................	8 lbs.	6.8	6.6	6.7	5.0	6.8	6.9	6.8	5.8	7.0	0.6	32.2	2.3	6.9
13..........	Dry lime-sulphur A*..................	6 lbs.	6.5	6.5	6.6	5.1	7.0	6.8	6.5	6.5	6.1	0	33.8	2.6	10.1
14..........	Check..............................	....	7.0	7.1	6.9	6.8	6.8	6.5	6.8	6.1	8.6	0.2	1.1	0	1.4

*Lead arsenate was used, unless otherwise indicated, at the rate of 2 lbs. in each 100 gallons of spray in the pink and all later applications.
†Quick lime was used in making this bordeaux.

Table 27.—Experiments at Morrice, 1927.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)				Injury to fruit (per cent)				
			Jonathan				Hubbardston		Jonathan		
			June 14	Aug. 3	Sept. 7	Oct. 5	Light Russet	Medium Russet	Light Russet	Medium Russet	Blossom-end injury
1.......	Lime-sulphur (Rain water from cistern used for this plot)*.....	2½ gal.	6.4	3.8	2.5	1.6	0	0	....	....	....
2.......	Lime-sulphur (Well water was used for this and all succeeding plots)*..........	2½ gal.	7.5	4.4	3.5	2.9	0	0	2.5	.3	0
3.......	Lime-sulphur.......... Lead arsenate..........	2½ gal. 1 lb.	6.9	4.5	3.1	2.2	0	0	2.7	0	0
4.......	Lime-sulphur.......... Lead arsenate..........	2½ gal. none	6.9	4.8	4.0	3.9	0	0	0	0	0
5.......	Lime-sulphur.......... Lead arsenate..........	1¼ gal. none	6.9	5.9	5.5	4.9	0	0	0	0	0
6.......	Lime-sulphur*.......... Iron sulphate..........	2½ gal. 1¼ lbs.	7.7	5.3	4.9	4.1	0	0	0	0	0
7.......	Lime-sulphur*.......... Iron sulphate..........	2½ gal. 9 lbs.	7.6	6.3	5.7	4.9	0	0	0	0	0
8.......	Lime-sulphur*.......... Aluminum sulphate..........	2½ gal. 9 lbs.	7.6	5.2	4.4	3.5	0	0	0	0	0
9.......	Lime-sulphur*..........	2½ gal.	7.0	4.2	3.5	2.5	0	0	....	....	....
10.......	Bordeaux (Ortho)*..........	4 lbs.	7.3	6.6	6.1	5.0	33.2	18.6†	....	....	....
11.......	Lime-sulphur (pink application)*.......... Mulsoid sulphur (petal-fall, two weeks and second brood applic.)	2½ gal. 8 lbs.	7.5	4.4	3.7	2.9	0	0	....	....	....
12.......	Lime-sulphur (pink and petal-fall applications)*.......... Mulsoid sulphur (two weeks and second-brood application).....	2½ gal. 8 lbs.	6.0	4.9	4.3	3.1	0	0	....	....	....
13.......	Check..........	....	....	....	....	....	0	0	0	0	0

*Lead arsenate unless otherwise indicated, was used in all plots at the rate of 2 lbs. in 100 gallons.
†There is also 7.4 per cent of heavy russet.

Table 28.—Experiments at Morrice, 1928.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)				Injuries to fruit (per cent)						
			Jonathan		Hubbard-ston	Wagener	Hubbardston			Jonathan			
			Aug. 16	Sept. 21	Sept. 14	Sept. 18	Light Russet	Medium Russet	Heavy Russet	Light Russet	Medium Russet	Heavy Russet	Blossom-end injury
1......	Lime-sulphur, Quick lime (Lime used in petal-fall, two weeks and second brood application).*	2½ gal. 8 lbs.	4.9	3.2	4.3	1.9	17.6	8.3	1.4	....	....	....	....
2......	Lime-sulphur, Quick lime (Lime used in all applic.)*	2½ gal. 8 lbs.	4.6	3.7	3.9	1.5	16.3	8.8	1.2	14.9	4.8	0.1	0.7
3......	Lime-sulphur*........................	2½ gal.	4.8	3.6	4.0	1.4	24.9	10.4	2.6	15.2	4.6	0	0.6
4......	Lime-sulphur*........................ Calcium sulphate......................	2½ gal. 4 lbs.	4.7	3.5	4.6	2.0	33.4	16.4	1.2	19.2	8.3	1.0	0.6
5......	Lime-sulphur*........................ Tobacco dust..........................	2½ gal. 5 lbs.	4.9	3.9	5.3	1.7	31.4	13.8	2.4	23.9	11.2	1.0	0.8
6......	Lime-sulphur, Iron sulphate (All applications except in second brood) Bordeaux (Second brood application)*...	2½ gal. 1¼ lbs. 2-2-100	5.5	6.2	6.3	3.4	26.2	6.1	1.2	14.8	3.6	0	0
7......	Lime-sulphur, Iron sulphate (All applications except second brood)* Bordeaux (second brood application).....	2½ gal. 2½ lbs. 2-2-100	6.4	6.3	6.2	3.2	32.8	11.4	1.1	16.8	2.3	0.3	0.2
8......	Lime-sulphur (prepink and pink applic.).. Lime-sulphur (petal-fall, two weeks and second brood application)*...........	2½ gal. 1 gal.	4.0	3.3	5.6	3.2	30.8	4.1	0.4	19.7	1.4	0	3.8
9......	Lime-sulphur (pre-pink and pink applic.). Lime-sulphur (petal-fall, two weeks and second brood application)*...........	2½ gal. 1½ gal.	4.6	3.0	5.8	2.2	34.6	8.9	0.1	23.7	2.4	0	6.1
10......	Lime-sulphur (pre-pink and pink applic.). Lime-sulphur (petal-fall, two weeks and second brood application)*...........	2½ gal. 2 gal.	4.9	3.6	5.6	1.7	24.7	4.3	0.4	27.3	13.3	0.3	18.7

Table 28.—Experiments at Morrice, 1928—Continued.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)				Injuries to fruit (per cent)						
			Jonathan		Hubbard-ston	Wagener	Hubbardston			Jonathan			
			Aug. 16	Sept. 21	Sept. 14	Sept. 18	Light Russet	Medium Russet	Heavy Russet	Light Russet	Medium Russet	Heavy Russet	Blossom-end injury
11......	Lime-sulphur*........................	2½ gal.	4.2	3.0	5.5	1.8	37.8	12.2	1.1	23.5	15.4	2.9	4.9
12......	Bordeaux (All applic. except petal-fall)†.. Lime-sulphur (petal-fall applic.)*........	2-2-100 2½ gal.	....	6.2	6.5	3.1	32.1	35.6	18.7	36.9	53.9	2.0	0.8
13......	Bordeaux (All applic. except petal-fall)*. Lime-sulphur } (petal-fall application).... Iron sulphate }	2-2-100 2½ gal. 1¼ lbs.	....	6.1	6.4	3.8	28.6	38.6	31.1	38.9	55.2	3.7	0.3
14......	Bordeaux (pre-pink and second brood application only)*................... Lime-sulphur } (pink, petal-fall and two- Iron sulphate } weeks application)	2-2-100 2½ gal. 1¼ lbs.	....	5.0	6.9	3.3	36.1	18.1	1.5	18.6	5.7	0	0.9
15......	Lime-sulphur......................... Calcium arsenate...................... Quick lime...........................	2½ gal. 2 lbs. 8 lbs.	....	3.8	5.5	2.7	35.4	6.7	0	....	....	....	....
16......	Koppers flotation sulphur*.............	10 lbs.	....	5.4	6.9	4.7	25.9	1.8	0.1	....	....	....	....
17......	Check..............................	....	7.3	7.1	7.4	5.0	46.0	1.9	0.2	26.6	0	0	0

*Lead arsenate was used, unless otherwise indicated, at the rate of 3 lbs. in each 100 gal. in the pink, petal-fall and two weeks application and 2 lbs.in the second brood spray.
†All bordeaux was made with quick lime.

Table 29.—Experiments at Morrice, 1929.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)					Injuries to fruit (per cent)					
			Jonathan	Hubbard-ston	Wagener	Baldwin	Spy	Jonathan			Baldwin		Spy
			Sept. 10	Sept. 11	Sept. 10	Sept. 10	Sept. 12	Light Russet	Medium Russet	Blossom-end injury	Light Russet	Medium Russet	Light Russet
1......	Bordeaux (Prepink and second brood application)*... Lime-sulphur } (Pink, petal-fall and two Iron sulphate } weeks application)	2-2-100 2½ gal. 1¼ lbs.	3.4	4.2	3.2	3.7	4.1	20.8	0	0	29.7	1.4	....
2......	Lime-sulphur*...	2½ gal.	2.4	2.4	1.1	1.6	2.0	18.5	0	6.6	39.6	7.8	....
3......	Lime-sulphur (Prepink application)*... Lime-sulphur } (Pink, petal-fall and Iron sulphate } two weeks application) Casein spreader } Bordeaux (second brood application)...	2½ gal. 2½ gal. 1¼ lbs. 1 lb. 2-2-100	3.6	3.8	3.1	3.4	3.2	20.8	0	0.2	29.1	2.2	4.9
4......	Lime-sulphur (prepink, pink and petal-fall application)*... Lime-sulphur } (two weeks application) Iron sulphate } Bordeaux (second brood application)...	2½ gal. 2½ gal. 1¼ lbs. 2-2-100	3.4	4.1	2.2	3.6	3.6	18.2	0	1.0	34.4	5.1	0.7
5......	Lime-sulphur } (prepink, pink, petal-fall Iron sulphate } and two weeks applic.)* Bordeaux (second brood application)...	2½ gal. 1¼ lbs. 2-2-100	4.1	4.0	3.1	2.9	4.4	17.4	0	0.2	29.3	2.6	1.0
6......	Lime-sulphur (prepink application)*... Lime-sulphur } (pink, petal-fall and two Iron sulphate } weeks application) Bordeaux (second brood application)...	2½ gal. 2½ gal. 1¼ lbs. 2-2-100	4.0	4.0	3.1	3.3	4.4	11.5	0	0	39.5	9.7	0.7
7......	Dry-lime-sulphur A*...	10 lbs.	2.5	2.9	1.7	1.8	3.5	26.7	0.6	6.1	30.5	20.4	2.5
8......	Lime-sulphur (same as Plot 2)...	2½ gal.	2.1	2.3	1.4	1.9	2.9	32.1	3.4	8.2	27.7	7.5	1.6

Table 29.—Experiments at Morrice, 1929—Continued

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)					Injuries to fruit (per cent)					
			Jonathan	Hubbard-ston	Wagener	Baldwin	Spy	Jonathan			Baldwin		Spy
			Sept. 10	Sept. 11	Sept. 10	Sept. 10	Sept. 12	Light Russet	Medium Russet	Blossom-end injury	Light Russet	Medium Russet	Light Russet
9......	Bordeaux (all applications except petal-fall)*—†......................... Lime-sulphur } (petal-fall application) Iron sulphate }	2-2-100 2½ gal. 1¼ lbs.	3.8	4.3	3.7	4.0	4.7	42.8	18.0‡	0	37.2	9.0	10.3
10......	Dry lime-sulphur A (prepink applic.)*.. Dry lime-sulphur A } (pink, petal-fall Iron sulphate } and two weeks application) Bordeaux (second brood application).....	10 lbs. 10 lbs. 1¼ lbs. 2-2-100	3.7	2.3	2.8	2.7	4.5	22.1	2.4	0.2	34.8	8.7	0.7
11......	Same as Plot 3*......................	....	3.4	3.8	3.1	....	4.4	29.1	2.6	0.2	....	....	2.0
12......	Same as Plot 1*......................	....	3.6	4.0	2.9	....	4.5	22.5	3.8	0.2	....	....	3.1
13......	Check..............................	....	....	....	6.2	....	5.3	10.5	0.5	0	....	....	4.0

*Lead arsenate was used, unless otherwise indicated at the rate of 3 lbs in 100 gallons in the pink, petal-fall and two weeks applications and 2 lbs. in the second brood.
†All bordeaux was made with quick lime.
‡There is also 2.9 per cent of heavy russet.

Table 30.—Experiments at Morrice, 1930.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)	Injuries to fruit (per cent)			
			Jonathan	Jonathan			
			Sept. 17	Light Russet	Medium Russet	Blossom-end injury	Scald
1	Lime-sulphur, Iron sulphate, Casein spreader } (All applications except second brood)* Bordeaux (second brood application)	2½ gal. 1¼ lbs. 1lb. 3-3-100†	4.4	21.9	0.9	0	0.9
2	Lime-sulphur, Iron sulphate } (All applications except second brood)*—‡ Bordeaux (second brood application)	2½ gal. 1¼ lbs. 3-3-100	4.6	7.4	0.2	0.1	0.4
3	Lime-sulphur (prepink and pink applications)* Koppers flotation sulphur (petal-fall, two weeks and second brood applications)	2½ gal. 16 lbs.	5.0	3.2	0	10.4	2.0
4	Calcium sulphide (Cal-Mo-Sul.)*	12½ lbs.	4.6	4.1	0	1.1	2.1
5	Dry-lime-sulphur A, Iron sulphate } (All applications except second brood)* Bordeaux (second brood application)	10 lbs. 1¼ lbs. 3-3-100	4.4	9.2	0	0.1	0.3
6	Lime-sulphur, Iron sulphate } (All applications except second brood)* Bordeaux (second brood application)	2½ gal. 1¼ lbs. 3-3-100	4.4	10.7	0.1	0.1	0.9
7	Lime-sulphur (prepink, pink and petal-fall applications)* Lime-sulphur, Iron sulphate } (two weeks application) Bordeaux (second brood application)	2½ gal. 2½ gal. 1¼ lbs. 3-3-100	4.4	9.4	0.1	0.1	0.2
8	Lime-sulphur, Iron sulphate, Calcium arsenate } (All applications except second brood) Bordeaux (second brood application)	2½ gal. 1¼ lbs. 2 lbs. 3-3-100	4.6	12.3	0.1	0.6	0.8
9	Lime-sulphur*	2½ gal.	4.1	12.9	0.7	0.8	2.6

Table 30.—Experiments at Morrice, 1930—Continued.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)	Injuries to fruit (per cent)			
			Jonathan	Jonathan			
			Sept. 17	Light Russet	Medium Russet	Blossom-end injury	Sunscald
10..........	Bordeaux (All applications except petal-fall)*—† Lime-sulphur } (petal-fall application) Iron sulphate }	3-3-100† $2\frac{1}{2}$ gal. $1\frac{1}{4}$ lbs.	4.9	47.5	21.8	0	0.3
11..........	Bordeaux (Delayed dormant and second brood applications)* Lime-sulphur } (pink, petal-fall and two weeks applications) Iron sulphate }	3-3-100 $2\frac{1}{2}$ gal. $1\frac{1}{4}$ lbs.	4.7	13.8	1.0	0.3	0
12..........	Lime-sulphur*	1 gal.	4.1	1.3	0	23.9	0.4
13..........	Dry lime-sulphur A*	4 lbs.	5.0	8.7	0.3	26.7	2.0
14..........	Dry lime-sulphur A*	10 lbs.	4.4	6.1	0.2	11.6	1.4
15..........	Check	....	4.6	1.2	0	0.2	0.7

*Lead arsenate was used, unless otherwise indicated, at the rate of 3 lbs. in 100 gallons in the pink, petal-fall and two-weeks applications and 2 lbs. in the second brood spray.
†Quick lime was used in making all bordeaux.
‡NuRexform lead arsenate was used in this plot.

Table 31.—Experiments at Belding, 1925.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)								Injury to fruit
			McIntosh				Baldwin				McIntosh
			Original	June 1	July 22	August 26	Original	June 1	July 22	August 26	Light russet (per cent)
1........	Bordeaux*—†................	4-8-100	7.0	6.9	6.8	6.7	6.6	6.2	6.1	5.7	39.6
2........	Lime-sulphur*................ Casein spreader...............	2½ gal. 1 lb.	7.4	7.2	7.1	5.4	6.6	5.2	5.2	3.6	38.1
3........	Lime-sulphur*...............	2½ gal.	7.4	7.3	7.2	6.2	6.5	5.8	5.1	4.9	14.4
4........	Lime-sulphur*................ Quick lime...................	2½ gal. 5 lbs.	7.7	7.5	7.4	7.0	6.5	5.4	5.3	4.4	10.7
5........	Lime-sulphur*................ Iron sulphate................	2½ gal. 1¼ lbs.	7.2	7.1	7.0	6.9	6.4	5.5	5.4	5.0	5.2
6........	Lime-sulphur*................ Cane sugar...................	2½ gal. 5 oz.	6.8	6.6	6.5	5.8	6.4	5.3	5.2	3.9	20.4
7........	Check.........................	....	7.1	7.0	6.9	6.9	6.5	6.2	6.1	6.1	8.5

*Lead arsenate was used at the rate of 2 lbs. in each 100 gallons of spray in the pink and all later applications.
†Quick lime was used in making this bordeaux.

Table 32.—Experiments at Belding, 1926.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)								Injury to fruit (per cent)	
			McIntosh				Baldwin				McIntosh	
			June 6	July 7	August 5	September 16	June 6	July 7	August 5	September 16	Light Russet	Medium Russet
1......	Ortho bordeaux*............	4 lbs.	....	....	....	....	....	....	....	....	88.6	11.3
2......	Bordeaux*—†..............	2-2-100	7.7	7.5	7.5	7.7	6.3	6.1	5.5	4.8	55.4	24.3
3......	Lime-sulphur*............. Casein spreader............	2½ gal. 1 lb.	6.8	6.5	6.2	5.8	6.1	5.7	5.6	4.4	4.4	0
4......	Lime-sulphur*.............	2½ gal.	6.8	6.3	5.9	5.7	6.1	5.5	5.5	4.5	8.8	0
5......	Lime-sulphur*............. Quick lime.................	2½ gal. 5 lbs.	6.9	6.4	6.2	6.0	6.5	5.8	5.7	4.6	3.3	0
6......	Sulfocide*................. Casein spreader............	½ gal. 2 lbs.	7.2	6.7	6.6	6.2	6.4	6.1	6.1	5.1	12.1	0
7......	Lime-sulphur*............. Iron sulphate..............	2½ gal. 1¼ lbs.	7.2	6.5	6.3	5.7	6.2	6.2	5.9	5.2	11.9	0
8......	Dry lime-sulphur A*........	10 lbs.	6.8	6.2	5.9	5.3	6.4	5.8	5.7	4.0	12.5	0
9......	Dry lime-sulphur B*........	10 lbs.	6.6	6.0	5.9	5.1	....	....	....	....	25.2	0
10......	Check.....................	....	7.3	6.8	6.5	6.6	6.1	5.9	6.1	5.6	0.1	0

*Lead arsenate was used at the rate of 2 lbs. in 100 gallons in the pink and all later applications.
†Made with quick lime.

Table 33.—Experiments at Belding, 1927.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average)				Injury to fruit (per cent)	
			Baldwin				McIntosh	
			June 21	July 29	September 2	October 12	Light Russet	Medium Russet
1	Bordeaux (Ortho)*	5 lbs.	5.9	5.6	5.3	4.4	39.8	25.1†
2	Lime-sulphur (pre-blossom and petal-fall applications)* Dry-mix (2 weeks and second brood applications)	2½ gal. 16 lbs.	5.6	4.7	4.7	2.4	2.2	0
3	Lime-sulphur*	2½ gal.	5.4	4.3	2.7	1.8	6.9	0
4	Lime-sulphur* Aluminum sulphate	2½ gal. 9 lbs.	5.8	5.2	4.6	3.4	3.2	0
5	Sulfocide* Casein spreader	½ gal. 2 lbs.	5.5	4.2	3.8	3.0	5.0	0
6	Lime-sulphur* Iron sulphate	2½ gal. 9 lbs.	5.6	5.3	4.1	3.5	5.7	0
7	Dry lime-sulphur A*	10 lbs.	5.0	3.8	2.5	1.9	15.6	....
8	Dry lime-sulphur B*	10 lbs.	....	....	....	....	18.3	0.6
9	Check	....	5.9	5.8	5.4	4.3	0	0

*Lead arsenate was used at the rate of 2 lbs. in 100 gallons of spray in the pink and all later applications.
†There is 4.2 per cent of heavy russet also.

Table 34.—Experiments at Belding, 1928.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average) September 19		Injury to fruit (per cent) McIntosh	
			Baldwin	McIntosh	Light Russet	Medium Russet
1	Bordeaux (All applications except petal-fall)*—† Lime-sulphur } (petal-fall application) Iron sulphate }	2-2-100 2½ gal. 1¼ lbs.	3.6	....	39.5	24.7‡
2	Lime-sulphur* Tobacco dust	2½ gal. 5 lbs.	2.3	....	....	....
3	Lime-sulphur*	2½ gal.	2.4	3.4	37.1	8.6
4	Lime-sulphur Calcium arsenate Quick lime	2½ gal. 2 lbs. 8 lbs.	2.7	3.9	11.9	0
5	Lime-sulphur } Iron sulphate } (prepink, pink, petal-fall, and two weeks applications) Calcium arsenate } Bordeaux } (second brood application) Calcium arsenate }	2½ gal. 1¼ lbs. 2 lbs. 2-2-100 2 lbs.	2.7	3.8	21.2	0.7
6	Lime-sulphur } (prepink, pink, petal-fall and two weeks applications)* Iron sulphate } Bordeaux (second brood application)	2½ gal. 1¼ lbs. 2-2-100	2.9	3.9	26.7	0.8
7	Lime-sulphur } (Lime used in all applications)* Quick lime }	2½ gal. 8 lbs.	1.6	3.2	12.4	0
8	Lime-sulphur } (Lime used petal-fall, two weeks and second brood applications)* Quick lime }	2½ gal. 8 lbs.	....	3.4	14.3	0.6
9	Check	....	4.6	4.6	0	0

*Lead arsenate used in all plots except where otherwise indicated.
†Quick lime used to make bordeaux.
‡There is also 9.5 per cent of heavy russet.

Table 35.—Experiments at Belding, 1929.

Plot	Materials	Amount in 100 gal.	Leaves on spurs (average) Baldwin September 5
1	Bordeaux*—†	2-2-100	3.9
2	Dry lime-sulphur A*	10 lbs.	1.3
3	Lime-sulphur*	2½ gal.	1.2
4	Lime-sulphur, Iron sulphate (All applications except second brood) Bordeaux (second brood application)	2½ gal. 1¼ lbs. 2-2-100	2.6

*Lead arsenate used with all materials.
†Lime-sulphur and iron sulphate, as in Plot 4, substituted in petal-fall application.

Table 36.—Experiments at Grand Rapids, 1928.

Plot	Materials	Amount in 100 gal.	Injury to fruit (per cent)					
			Stayman			Grimes		
			Light Russet	Medium Russet	Heavy Russet	Light Russet	Medium Russet	Heavy Russet
1	Corona copper carbonate*	2 lbs.	23	33	41	58	42	0
2	Corona 50% plus (copper carbonate)*	2 lbs.	12	38	50	49	48	2
3	Pure basic copper sulphate*	2 lbs.	10	39	50	38	53	7
4	Let-down basic copper sulphate*	2 lbs.	20	29	44	39	52	8
5	Bordeaux*	2-2-100	33	47	16	59	38	2
6	Lime-sulphur*	2½ gal.	31	40	13	69	29	0
7	Check	....	0	0	0	62	37	0

*Lead arsenate was used with all materials in all applications except the delayed dormant.

Table 37.—Experiments at Grand Rapids, 1929.

Plot	Materials	Amount in 100 gal.	Injury to fruit (per cent)		
			Duchess	Grimes	
			Light Russet	Light Russet	Medium Russet
1	Lime-sulphur (All applications)*	2½ gal.	Practically none	29.7	2.7
2	Lime-sulphur (delayed dormant application)* Lime-sulphur } (pink, petal-fall and 2 weeks applications) Iron sulphate } Bordeaux (second brood application)	2½ gal. 2½ gal. 1¼ lbs. 2-2-100	Practically none	43.2	2.9
3	Lime-sulphur } (All applications except second brood)* Iron sulphate } Bordeaux (second brood application)	2½ gal. 1¼ lbs. 2-2-100	Practically none	38.8	1.9
4	Bordeaux (delayed dormant and second brood applications)* Lime-sulphur } (pink, petal-fall and 2 weeks applications) Iron sulphate }	2-2-100 2½ gal. 1¼ lbs.	Large percentage of apples with light netting of russet.	51.5	8.7

*Lead arsenate was used with all materials.