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APPLE POWDERY MILDEW AND ITS CONTROL IN THE PAJARO VALLEY.[1]

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INTRODUCTION.

Apple powdery mildew is a fungous disease which attacks the foliage and young twig growth of the apple. Occasionally it occurs on pears, more particularly on nursery stock in damp or foggy localities, and at times it seriously injures quinces. The disease is quite widely distributed over the world and may be caused by either of two very similar fungi, namely, *Podosphaera leucotricha* (E. and E.) Salm., and *P. oxyacanthae* (DC) de Bary.[3]

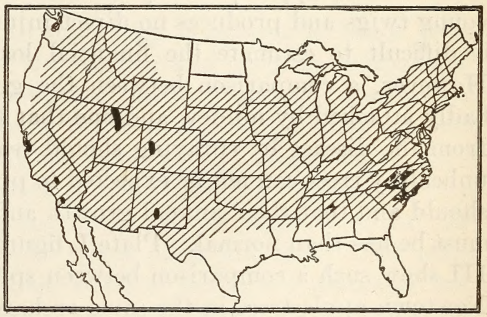

Fig. 1.—Map of the United States, the shaded area showing where apple powdery mildew occurs occasionally and the black spots where serious outbreaks are common.

Powdery mildew of the apple occurs at least occasionally in nearly all parts of the United States and is reported from some Provinces of Canada. It is widely distributed in Europe and occurs also in Australia, New Zealand, and Japan. In the central and eastern United States it has been known for many years as a more or less serious disease of nursery stock, but it is only during the last few years that it has been reported as doing any considerable damage in bearing orchards. In the western United States, however, from

[1] This bulletin is intended to assist apple growers in dealing with a fungous disease which is becoming a serious menace to their industry. It is suitable for distribution in the apple-growing sections west of the Rocky Mountains and in certain limited areas east of the Rocky Mountains, as shown on the map.

[2] These investigations were carried on cooperatively between the Office of Fruit-Disease Investigations of the Bureau of Plant Industry and the office of the county horticultural commissioner of Santa Cruz County, located at Watsonville, Cal.

[3] See also page 5.

Utah and New Mexico westward, and more particularly along the Pacific coast, climatic conditions appear to favor its development into a serious menace to successful apple growing. Throughout this whole territory it is increasing in its distribution, and in those districts in which it is already established it is gradually becoming a serious orchard disease. It occurs more or less commonly throughout Washington and Oregon and in some districts has already acquired sufficient importance to be given regular attention in the annual schedule of spraying applications. At the present time the orchards of the Pajaro Valley in California suffer more from apple powdery mildew caused by *Podosphaera leucotricha* than do those of any other large apple-growing district in the United States. It is true that in one or two small coast sections in California the disease causes even greater damage to the trees, but its commercial importance in those districts is not comparable with that in the Pajaro Valley, where the annual output of apples is about 3,500 carloads of packed fruit. In that section more than 80 per cent of the apple acreage is in Yellow Newtowns and Yellow Bellflowers, both of which varieties are particularly susceptible to mildew attack.

Throughout the western United States, according to the writers' observations, apple powdery mildew attacks only the foliage and young twigs and produces no direct injury of the fruit; therefore, it is difficult to estimate the financial loss which the disease causes. However, a comparison between the general appearance of a tree badly attacked by mildew and one that has been kept relatively free from the disease by spraying should readily convince one that such unhealthy trees can not be expected to produce the kind of crops they should and that their annual growth and increase in bearing surface must be less than normal. Plate I, figures 1 and 2, and Plates II and III show such a comparison between sprayed and unsprayed Yellow Newtown apple trees in the same orchard. Badly diseased orchards that are allowed to remain untreated become more and more seriously infected each year. The cumulative effect of such a gradually increasing general infection results in a decided decline in the vigor and appearance of the orchard.

The commercial importance of controlling apple powdery mildew has long been recognized, and many investigators, both in America and abroad, have given attention to the problem. As early as 1889[1] the Department of Agriculture conducted investigations and issued spraying recommendations for the control of the disease on nursery stock, and since that time numerous formulas for spray mixtures and instructions for spraying have been published by various State experiment stations. Meantime, similar investigations have been in

[1] Galloway, B. T. Experiments in the treatment of pear leaf-blight and the apple powdery mildew. U. S. Dept. of Agr., Section of Vegetable Pathology, Cir. 8, 11 p., 1889.

progress in Europe and elsewhere. In 1907, when the work in the Pajaro Valley was started, it was naturally assumed that some of the spray mixtures recommended, either in this country or abroad, would prove successful in controlling the disease in that district. Such was not the case, however, and several seasons have been spent in developing a method that can be used satisfactorily.[1] One source of delay in arriving at a practical solution of the problem has been the peculiar climatic conditions of the Pajaro Valley, which distinguish it from any other large apple district in the United States. It will not be out of place to call attention to some of these peculiarities.

CLIMATIC CONDITIONS OF THE PAJARO VALLEY.

The Pajaro Valley lies along the northern shore of Monterey Bay and is situated about 75 miles south of San Francisco Bay. As is common to California in general, the year is divided into two seasons, the rainy and the dry. The rainy season extends from the latter part of October to the month of April, and during that time there is an average precipitation of about 25 inches. Throughout the remainder of the year showers are rare and of practically no importance. The winter weather is mild and comparatively little frost occurs.

In the summer and early fall the valley is subject to winds from the ocean. These winds are of low velocity and produce no appreciable wind damage. They commence about noon and continue to blow until evening. As a result the evenings and nights are cool or even chilly. Very frequently the winds bring in fogs, which begin to cover the valley about 4 o'clock in the afternoon and remain until 9 or 10 o'clock the following morning. These fogs, of course, obscure the sun. They are of two types, high and low. The main body of the high fogs is at an elevation of perhaps a thousand feet, and in consequence the foliage of the trees is not much dampened. On the other hand, the land fogs lie close to the ground and envelop the trees, drenching the foliage so that the leaves often drip profusely during the night and early morning. This foggy weather is not continuous, but is interspersed with clear periods of 2 to 10 days. During the foggy weather the daily fluctuation of the temperature is between 50° and 65° F., and in the clear periods the range is from 65° to 80° F. Temperatures above 90° F. are rarely experienced more than once or twice during the summer.

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[1] During the time these investigations have been in progress near Watsonville, Cal., a considerable portion of the orchards of the C. H. Rodgers estate has been given over each year to experimental work, and in the past two years spraying and pruning experiments have also been conducted in the orchard of Mr. O. D. Stoesser. In addition, the hearty cooperation of many other growers in the valley has been of material assistance in determining from a commercial standpoint the feasibility of the control methods recommended.

BEARING OF CLIMATIC CONDITIONS ON THE SPRAYING PROBLEM.

It is very probable that this cool, foggy climate with its lesser amount of sunshine is the factor which produces apple foliage that has a lower resistance to injurious spray materials and a higher susceptibility to powdery mildew attack than that grown in districts where more intense sunshine and higher temperatures obtain. Also, the presence of fog and dew moisture on the foliage tends to dissolve and decompose some spray materials after they have been applied. In fact, the conditions surrounding the problem of spray injury in the Pajaro Valley are distinctly different from those in the eastern United States, for instance, where the foliage is frequently subjected to washing rains. In the latter case the injurious substances liberated by the decomposition of the spray materials on the foliage are, to a great extent, washed off as rapidly as they are formed. In the Pajaro Valley, on the other hand, no such washing occurs, and the injurious substances remain on the leaves, to be dissolved night after night by the fog and dew and absorbed directly through the leaf surface or through abrasions, thereby producing foliage injury. This susceptibility of the foliage to spray injury has been especially noticeable in the case of arsenicals. Paris green, even of the best grade, can not be used, on account of the severe foliage injury which it produces. The ordinary type of lead arsenate, known as the acid arsenate, that is used freely on apple foliage in most parts of the United States, is capable of causing serious burning and defoliation of the trees in the Pajaro Valley, and it was not until the much more stable so-called triplumbic, or neutral, lead arsenate was introduced that a safe arsenical was available. This tendency to decompose and cause burning is shown by other spray materials. However, injury from Bordeaux mixture, for instance, is not as severe in the Pajaro Valley as it is in the humid Eastern States. Possibly fog moisture is not as free a solvent of resistant copper compounds as is rain water. Nevertheless, Bordeaux mixture and other copper sprays are too injurious to permit of their repeated use in this valley. The same is true of lime-sulphur solution and other soluble sulphids which naturally suggest themselves as mildew sprays. Lime-sulphur solution of a strength commonly employed with success throughout the East for summer spraying can not possibly be used in the Pajaro Valley on account of the foliage injury which it produces.

Extensive field tests of spray materials have been carried out by the writers, and further examples might be cited illustrating the striking susceptibility of Pajaro Valley apple foliage to injury from sprays. Several years of investigations and observations have convinced the writers that the trees of that district are in a particularly sensitive

physiologic condition and that almost any artificial treatment given them is liable to bring striking results, either beneficial or injurious. In fact, precipitated sulphur may be applied as a spray in such a manner as to produce two distinct physiologic effects, one markedly beneficial and the other decidedly injurious.

APPLE POWDERY MILDEW.

Apple powdery mildew, as has been stated, may be caused by either *Podosphaera oxyacanthae* or *P. leucotricha*, formerly called *Sphaerotheca mali* (Duby) Burr. *Oidium farinosum* Cooke, which is frequently reported as the cause of the disease, is probably, according to Salmon, the conidial form of *P. leucotricha*. It is also probable that in the absence of what is termed the perfect stage the fungus is often assumed to be *P. oxyacanthae* when *P. leucotricha* is the form actually present, though both species exist on the cultivated apple in the United States. The species occurring in the Pajaro Valley is *P. leucotricha*. The identity of the fungus has been determined by repeated examinations of the perfect stage, which occurs frequently in that locality on the twigs, though not on the leaves. However, the following description of *P. leucotricha* and its life history will apply very well to *P. oxyacanthae* except for certain technical differences, some of which will be mentioned.

As has been stated, the disease attacks the foliage and current year's twig growth. Infection of the young fruit is extremely rare, and only occasionally does one find a flower-cluster bud that has been attacked. In the latter case the entire individual flowers are usually involved, the floral organs are reduced in size and much deformed, and the stems are short and thick. (Pl. IV, fig. 2.)

Mildewed areas on the leaves occur most commonly on the under sides. They are white or grayish, and the term "powdery" very well describes their mealy appearance. The diseased spots may vary in size from a point invisible to the naked eye to patches three-fourths of an inch or more in diameter, and several of these may become established on a single leaf. In a large percentage of cases the entire upper and lower surfaces of the leaf become involved. Mildewed leaves are crinkled and stunted and often very much narrowed, owing to the fact that the growth and expansion of the leaf tissue are checked in the areas covered by the fungus. Plate V, figure 2, illustrates this crinkling and stunting, and Plate IV, figure 1, illustrates the narrowing. In the Pajaro Valley the disease makes such rapid progress during the spring and summer that by the end of the leaf-forming season it is difficult to find normal, healthy leaves in any unsprayed Yellow Newtown or Yellow Bellflower orchard.

When a virulent infection becomes established on a leaf, the mildew frequently extends down the petiole to the twig, where it may continue to grow until it covers practically the entire surface of the bark. In such cases the new leaves become badly infected as rapidly as they come out. Plate IV, figure 1, illustrates this condition. Mildewed shoots are stunted in their development, the internodes are very much shortened, and a year's growth may be compressed into an inch or two. Plate IV, figure 2, and Plate VI, figure 2, show a number of examples, and it will be seen that in many cases the affected portion of the twig is considerably thickened. The ends of many of these diseased twigs die back during the winter, and in the following spring a shoot is sent out from a lateral bud, as shown in Plate IV, figure 2, *a*. In the case of the largest twig shown in Plate IV, figure 2, this dying back of the terminals and their replacement by laterals has occurred twice, as shown at *a* and *a'*. Some idea of the abundance of these twig infections can be obtained from Plate I, figure 1, an unsprayed tree, in which it will be seen that practically all of the terminals have been attacked and the greater portion of their foliage has died and dropped off, the few remaining leaves being stunted and distorted. Plate I, figure 2, shows a sprayed tree in the same block as that shown in Plate I, figure 1. A close examination of the size and abundance of the leaves shown in Plate I, figure 1, as compared with those shown in Plate I, figure 2, will impress one with the necessity of controlling the mildew if the vigor and future crop prospects of the tree are to be given proper consideration. Similar comparisons may be made between Plates II and III, though the illustrations do not bring out the strong contrast which exists between the sprayed and unsprayed trees. In winter, when the foliage is off the trees, the grayish mildew covering remains on the twigs, and they glisten in the sunlight when viewed from the proper angle. One is astonished at their abundance, for unsprayed trees fairly bristle with them, and it is probable that in a third of the orchards of the valley more than 50 per cent of the terminals are diseased.

Under the microscope the fungus presents the appearance of a much-branched and loosely interwoven tangle of very fine threads lying on the surface of the leaf or shoot. Scattered all through this tangle and forming a powdery layer on its surface are enormous numbers of minute reproductive bodies called conidia, or summer spores. Collectively the fine fungous threads are termed the mycelium. The mycelial threads branch and rebranch as they grow over the surface of a leaf or shoot (fig. 2), and at intervals short, saclike processes, called haustoria, penetrate the outer, or epidermal, layer of the leaf or twig and by means of these haustoria the fungus absorbs its nourishment. Thus the mildew derives its food mate-

rials from that particular portion of the leaf or twig surface upon which it is growing.

The very characteristic powdery appearance of the mildew (Pl. VI, fig. 2) is due, as stated above, to enormous numbers of summer spores. These are produced in chains (fig. 2) from certain branches of the mycelium, and their function is to start new mildew infections during the summer. The chains readily break up into individual spores, which are very light and are easily carried about

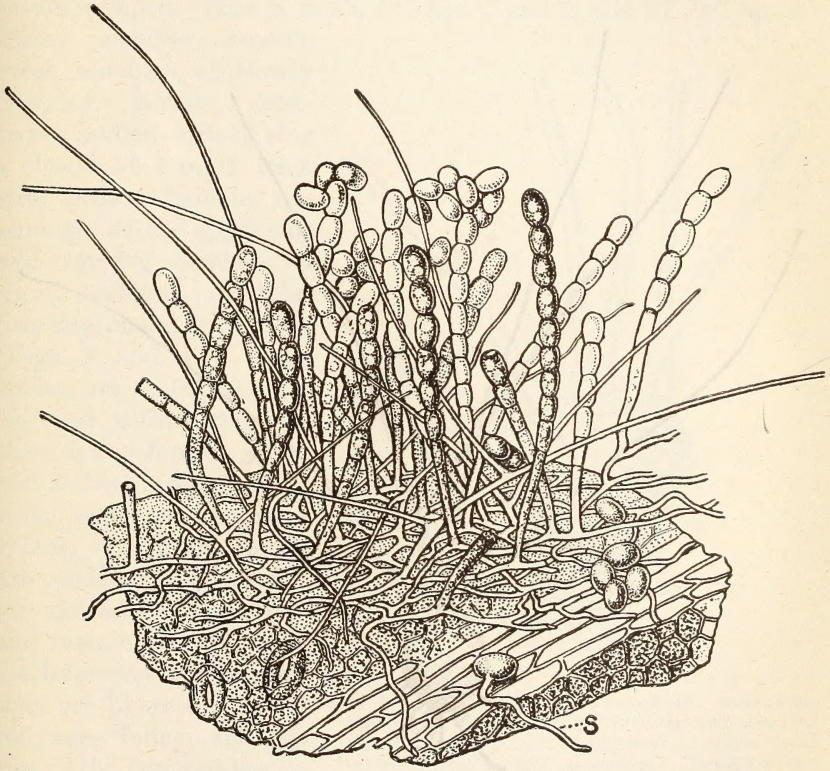

FIG. 2.—Peach mildew growing on the surface of a peach leaf. Apple powdery mildew has much the same appearance. At *s* a summer spore is shown germinating. Highly magnified. (After Tulasne.)

by the wind. When a spore lodges in a suitable place, such as the under side of the young leaf, it quickly germinates, if the moisture conditions are suitable, and sends out a small, threadlike germ tube (fig. 2, *s*), which is the beginning of a new mycelium, and by this means a new infection is established. These new mildewed areas immediately begin to form and throw off conidia in large numbers. The individual leaves are susceptible to infection during their entire growing period and up to the time when they become fully matured.

Very early in the season there is a period when great numbers of what appear to be mild infections establish themselves and cause a characteristic crinkling of the foliage. These infections soon die out and the damage done is not particularly serious, though it is undoubtedly of some importance.

The climatic conditions of the Pajaro Valley offer excellent opportunity for the establishment and progress of the mildew. The fogs furnish excellent moisture conditions for the germination of the spores, and it is probable that the somewhat peculiar climatic condi-

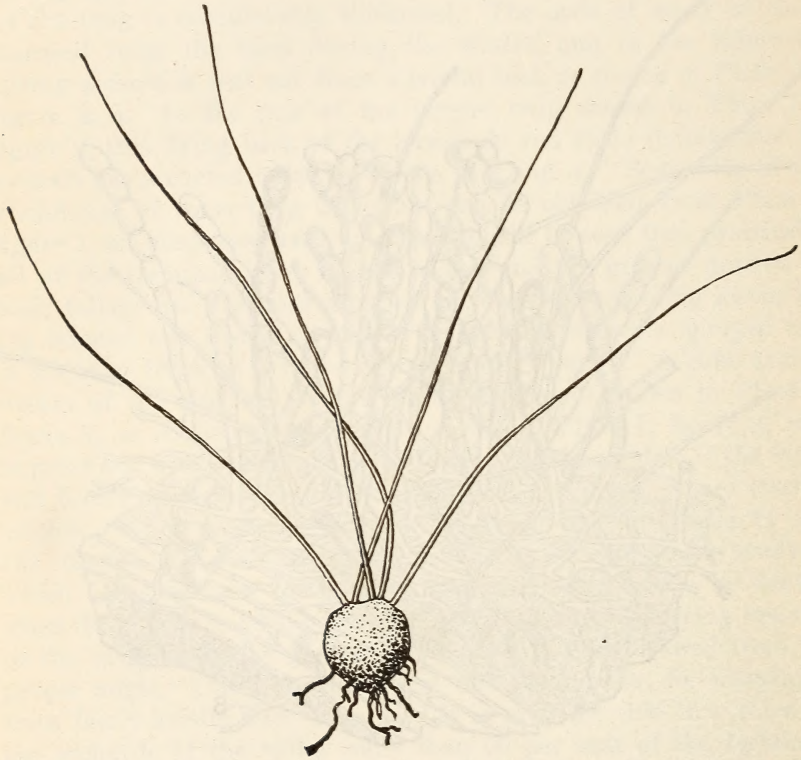

FIG. 3.—A perithecium of *Podosphaera leucotricha*, showing the two types of appendages. Magnified 90 times. (After Grout.)

tions of the valley influence the character of the foliage in a way to make it more than normally susceptible to infection. The result is that unless proper protection by spraying is provided, 90 per cent of the foliage of Yellow Newtowns and Yellow Bellflowers may become diseased before the end of the growing season.

The summer spores, or conidia, that have just been discussed serve only to spread the summer infections. They are not long lived, and therefore are not capable of carrying the mildew over from fall until the next spring. Furthermore, the mycelium on the twigs dies

during the latter part of the summer and fall, and thus plays no part in starting the disease the following spring. The natural method by which the fungus is able to bridge over the winter period is by means of another kind of reproductive bodies frequently called winter spores. This stage of the life history of the fungus develops only occasionally in most localities, but is particularly abundant in the Pajaro Valley. If a careful examination of vigorous twig infections be made about the first of July or shortly thereafter, it will be seen that on many of them irregular, dark, smoky-looking patches have developed. (See *p*, in Pl. IV, figs. 1 and 2, and Pl. VI, fig. 2.) These patches contain great numbers of closely crowded, globose, dark-brown bodies, each having a cluster of 4 to 11 long, stiff, brown, hairlike appendages on the upper side and varying numbers of short, tortuous, irregular processes on the under side. (Figs. 3 and 4.) These bodies are called perithecia, and within each one there is developed a single saclike body (fig. 4, *a*), in which eight so-called ascospores, or winter spores, are produced.[1] These winter spores are long lived and remain dormant until the following spring, when they are liberated, fall on the young foliage, and give rise to the first mildew infections of the season.

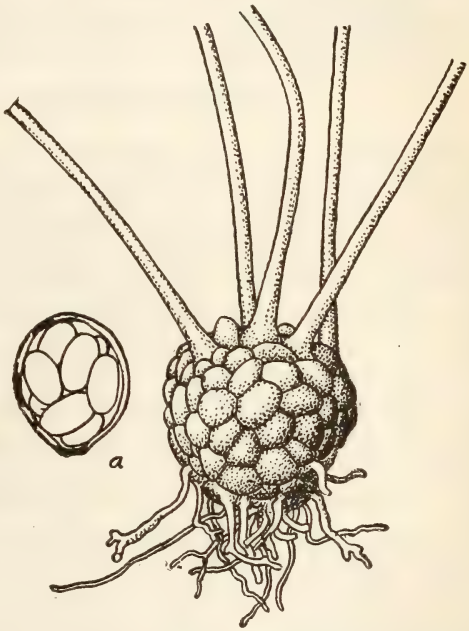

FIG. 4.—A perithecium of *Podosphaera leucotricha*, showing details of the perithecium wall and the basal appendages. At *a* is shown a single ascus which contains eight ascospores. Magnified 312 times. (After Grout.)

Careful observations have led the writers to the conclusion that in the Pajaro Valley this method of bridging over the winter season amounts to practically nothing in the matter of starting the first infections of the following year. It may be that relatively a very small percentage are established by this means, but the really important source is in what the writers have termed the dormant-bud infections. It can be easily seen that in such serious twig infections

[1] In *Podosphaera oxyacanthae* there is a tendency for the perithecia to be more scattered. The appendages, which are more or less equatorially placed, are of only one type. They are spreading and dichotomously branched at the tips.

as are shown in Plate IV, figures 1 and 2, and Plate VI, figure 2, the mildew growing over the surface of the shoots has an excellent opportunity to work its way in between the bud scales and penetrate both the lateral and terminal buds. This actually happens, and within these buds the mildew passes the winter in a dormant condition. The following spring, as the infected buds begin to open, the mildew commences to grow and keeps pace with the development of the new twigs.[1] Hence, infected shoots appear all over the trees as soon as they leaf out in the spring. The mildew growing on the young leaf and twig tissue is particularly virulent and produces summer spores in great abundance. It is not surprising, therefore, that a rapid infection of the healthy foliage soon takes place and that eventually practically all the leaves on the tree become diseased.

SUSCEPTIBILITY OF VARIETIES.

No varieties of apples grown in the Pajaro Valley are immune from powdery mildew, but some are more seriously affected than others. The relative susceptibility of different varieties will probably be found to vary in different apple-growing districts, depending, among other factors, upon the effect which the local climatic and other conditions have on the foliage vigor. In general, the varieties that produce strong, vigorous foliage are less susceptible than the more delicately growing ones. In this connection it is interesting to note that in the Pajaro Valley the Yellow Newtown, which is one of the most susceptible varieties, can apparently be made much less susceptible if the vigor of the foliage be increased by stimulation such as comes from spraying with very finely divided forms of sulphur. A list of the most susceptible varieties grown in the Pajaro Valley includes the Yellow Newtown, Yellow Bellflower, Smith (Smith's Cider), Missouri (Missouri Pippin), Esopus (Spitzenberg), and Gravenstein. The varieties that are less severely attacked are the White Pearmain (White Winter Pearmain), Winter Pearmain (Red Pearmain), Red Astrachan, Rhode Island Greening, and Langford.

SPRAYING EXPERIMENTS.

At the beginning of the writers' investigations it was assumed that the winter spores were the important source of the first infections in the spring, and the significance of what they have called the dormant-bud infections was not realized. It appeared, therefore, that there were two phases of the spraying scheme: (1) The winter spraying, directed toward killing the winter spores on the twigs, and (2) the

[1] Other investigators have reported a similar wintering over of the mycelium of apple and other mildews, but its occurrence in the Pajaro Valley is particularly noticeable because of its abundance and bearing on the problem of mildew control.

spring and summer spraying, intended to prevent foliage and twig infection and to kill out any mildew that had become established.

WINTER SPRAYING.

The experiments in dormant spraying were conducted through two winters. About 16 different materials were used, some of which were tested on several plats and in various strengths. Among the mixtures used were Bordeaux mixture, lime-sulphur solution, various soluble sulphids, copper sulphate, sulphuric acid (alone and in combination with copper sulphate and iron sulphate), and various soluble copper salts. The results showed that the plats which received the various dormant sprayings were just as badly attacked by mildew the following spring as those which were not sprayed.

FOLIAGE SPRAYING.

While the investigations in winter spraying were in progress, it became evident that the dormant or winter spores played a very unimportant part in establishing the first infections the following spring. It was seen that on each tree great numbers of mildewed twigs developed from dormant-bud infections, and that on these diseased twigs summer spores were produced in quantities and served to infect the healthy foliage as it came out.

The work of winter spraying for the direct control of the mildew was, therefore, dropped, though it was taken up again later from a different standpoint. Attention was given to finding a suitable fungicide for foliage spraying and a practical method of reducing to a minimum the number of dormant-bud infections.

About 125 different materials have been tested for foliage spraying, and many of them have been used in several different strengths. Experiments with the more promising ones have been repeated through several seasons, and the investigations have been in progress six years. For the purposes of this bulletin it will not be necessary to give a detailed account of the experimental work, but a brief statement of some of the results will not be out of place. It will be remembered that these remarks apply particularly to the Pajaro Valley, though for the most part they will probably hold true for other sections as well.

Copper compounds in general can not be used, on account of the leaf burning and fruit injury which they cause. Bordeaux mixture gives very poor control of apple powdery mildew. Copper acetate and copper oxychlorid give fair control of the mildew, but they can not be used repeatedly on account of their fruit and foliage injuring properties. Dilute lime-sulphur solution and solutions of the soluble sulphids in general, such as potassium and sodium sulphid, can not

be used, on account of the severe foliage injury resulting when they are employed in sufficient concentration to be effective against the mildew.

At present sulphur in some very finely divided form is the most efficient fungicide against apple powdery mildew. However, ordinary ground sulphur, sulphur flour, and flowers of sulphur, or sublimed sulphur, are all far too coarse to give appreciable results. The extremely finely divided form known to the chemist as precipitated sulphur and the still finer form known as colloidal sulphur are both particularly effective against the mildew.

In 1909 one of the writers[1] published a method for preparing what has been called iron-sulphid spray.[2] It was made by precipitating a solution of iron sulphate (copperas) with the required amount of lime-sulphur solution. Twenty pounds of iron sulphate were used in preparing 200 gallons of the spray mixture. By stirring together the lime-sulphur solution and a solution of iron sulphate, a black, muddy precipitate is formed, which contains precipitated sulphur, iron sulphid, and calcium sulphate. This spray was found particularly effective against the apple powdery mildew. It also possessed the very desirable property of stimulating a vigorous foliage growth, but it was found that serious injury in the form of leaf shedding and fruit dropping might result unless great care was exercised in applying it. Subsequent investigations showed that of the three compounds contained in this iron-sulphid mixture the precipitated sulphur is the ingredient which gives the preparation its properties as a fungicide, and it is at the same time responsible for the physiologic effects seen in the fruit and foliage shedding and in the stimulation of a more vigorous foliage growth. Pure precipitated sulphur used in amounts equivalent to that contained in the iron-sulphid mixture produced effects similar in all respects to those obtained from the iron-sulphid spray, and the same was true of colloidal sulphur, which is sulphur in a much more finely divided form than precipitated sulphur. Similar results were obtained from still other mixtures containing very finely divided sulphur.

From these investigations, which extended over several seasons, it became evident that aside from their power to control mildew, precipitated and other very finely divided forms of sulphur were capable of producing what may be termed sulphur effects. These sulphur effects are of a physiologic nature, and their intensity is

[1] Volck, W. H. The apple powdery mildew in the Pajaro Valley. Office of County Entomologist for Monterey and Santa Cruz Counties, Cal. Special Bul. No. 1. 1909.

[2] The expression "iron-sulphid spray" or "iron-sulphid mixture" will be used in this publication to refer to the mixture prepared from iron sulphate and lime-sulphur solution. The compound sold by chemical dealers under the name of iron sulphid is an entirely different substance and is of no value as a spray material.

proportional to the sulphur content of the spray mixture employed. If the first spraying is delayed until the apples are an inch or more in diameter and a spray mixture containing a relatively large amount of sulphur is used, a heavy shedding of fruit and foliage may be expected to follow. The leaves that fall are turgid and green and look in all respects fresh and normal. In bad cases the foliage shedding may be so severe as to leave the trees bare. The fruit that drops is also normal in appearance and may amount to 50 per cent of the crop. The loss of foliage is usually more than replaced by the vigorous production of new, extra-large leaves. Spraying with very weak mixtures brings about an increased foliage growth without causing leaf dropping. It is therefore evident that this unusual foliage production is not a reaction to any leaf pruning caused by spraying.

It might seem that the increased foliage growth is only the normal production of new growth to be expected as a result of the mildew control. That this, however, is not the case and that sulphur spraying has an actual stimulating effect seems to be a clearly established fact. Plate V, figure 1, shows two twigs from a tree that was not sprayed until considerable growth had been made. The first leaves that came out in the spring, those at the bases of the twigs, were of fair size. Gradually, as the new leaves appeared, they became more and more infected with mildew, and when the twigs had grown to the length indicated by the letter *T* in the figures, the leaves were small, distorted, and badly diseased. Very little more growth could have been expected. At that time the tree was sprayed with a mixture made by dissolving sulphur in carbon disulphid and emulsifying this solution with ammonia soap. Such a spray leaves a very fine coating of sulphur all over the foliage. Almost immediately growth was resumed and conspicuously large leaves were sent out. The photograph reproduced as Plate V, figure 1, was taken some time after the spraying was done, and no spray had been applied meantime. In other words, the extra growth of leaves took place after the spray was applied and their large size was not due to killing any mildew that was on them or to preventing infection, because they were not out at the time the spraying was done, and therefore they received none of the application. Thus, it seems evident that the spraying itself stimulated a new growth of foliage.

One type of fruit injury that may result from sulphur spraying is shown in Plate VI, figure 1. A strong dosage of iron-sulphid mixture was applied after the fruit had become partly grown. Shortly after the application was made there were several days of very hot weather, and on the exposed sides of the fruit, where the hot sun had

an opportunity to act on heavy sulphur deposits, the skin and outer layers of the flesh became brown and leathery. Mild cases of such injury have very much the appearance of ordinary sun scald, but when the damage becomes more serious the growth of the affected area is checked and the fruit cracks open. This type of injury has developed only occasionally, and then only when a strong dosage of sulphur or iron-sulphid mixture has been used. No such damage has ever been produced by the weak dosages of sulphur that are recommended in this bulletin for mildew control.

When it became evident that the tendency to cause fruit and foliage dropping was one of the general properties of these finely divided forms of sulphur, attention was turned to the investigation of a large number of other materials, in the hope that some substance might be found which would prove as effective as sulphur against the mildew and yet be free from the injurious property of causing fruit and foliage to drop. Among such substances tested, the most satisfactory results in mildew control were obtained from a number of dye materials. Fifty or more commercial dyes and laboratory stains were tested, and it was found that a number of them, when applied in water solutions, were capable of staining the mycelium and killing the mildew. Such sprays, however, are curative rather than preventive in their action, and while, with the exception of eosin, no injurious physiologic effects were encountered, their fungicidal properties were not entirely satisfactory.

Meantime, investigations with the iron-sulphid and other precipitated sulphur sprays were continued, and it has been found that by using weak mixtures, starting the spraying early, and repeating it frequently a very satisfactory mildew control can be obtained without danger of causing fruit to drop. Thus, after six years of investigations, in which 250 or 300 spraying experiments were conducted and over 100 different materials tested, sulphur in some very finely divided form still remains the most satisfactory fungicide for use against apple powdery mildew in the Pajaro Valley.

It may be repeated here that those forms of sulphur known commercially as sublimed sulphur, or flowers of sulphur, sulphur flour, and ground sulphur are far too coarse to be effective. Sulphur in its colloidal form gives excellent mildew control and possesses some distinct advantages of its own, especially in the matter of covering power. Certain difficulties involved in its preparation, however, prevent the grower from making his own supply. Precipitated sulphur may be made in a number of different ways, but what is here called the iron-sulphid mixture is the simplest and safest form in which the grower can prepare it.

Fig. 1.—Yellow Newtown Apple Tree, Unsprayed and Unpruned, Showing Scanty Foliage, Small Leaves, and Bare, Mildewed Tips.

Photographed in August, 1911.

Fig. 2.—Yellow Newtown Apple Tree Near the One Shown in Figure 1, Showing the Results of One Season's Spraying with Iron-Sulphid Mixture. Unpruned.

Note the abundance of foliage, the size of the leaves, and the scarcity of mildewed tips. Photographed in August, 1911.

YELLOW NEWTOWN APPLE TREE, UNSPRAYED AND UNPRUNED, SHOWING SCANTY FOLIAGE, SMALL LEAVES, AND MILDEWED TIPS.

Photographed in August, 1911.

YELLOW NEWTOWN APPLE TREE NEAR THE ONE ILLUSTRATED IN PLATE II, SHOWING THE RESULTS FROM TWO YEARS' SPRAYING WITH IRON-SULPHID MIXTURE.

Note the abundance of foliage, the size of the leaves, and the scarcity of mildewed tips. Photographed in August, 1911.

FIG. 1.—YELLOW NEWTOWN APPLE TWIGS.

Practically the entire bark and leaf surface of most of the twigs is covered with mildew. The badly diseased leaves are long and narrow. Many have died and dropped off. Patches of perithecia are seen at *p*. Photographed in July, 1911.

FIG. 2.—YELLOW NEWTOWN FLOWERS AND TWIGS.

The cluster of flowers (A) is completely covered with mildew. Photographed April 15, 1913. The twigs (B), similar to those in figure 1, show stunted growth and enlarged diameter of the diseased portion. *a* and *a'* are diseased laterals sent out from infected buds after the ends, *e*, of the previous year's growth had died back. Photographed in July, 1911.

FIG. 1.—YELLOW NEWTOWN APPLE TWIGS.

The trees were unsprayed until the twigs were of the length indicated at T. The vigorous growth from that point on resulted from a single application of a carbon disulphid and sulphur emulsion. Photographed June 12, 1911.

FIG. 2.—YELLOW NEWTOWN APPLE TWIG.

Typical mildewed foliage, showing the stunting and crinkling. (After Volck.)

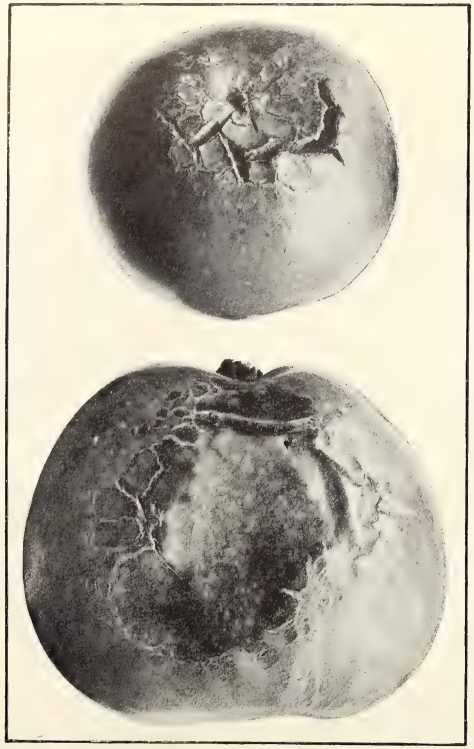

FIG. 1.—YELLOW NEWTOWN APPLES, SHOWING SULPHUR INJURY.

This injury resulted from the hot sun acting on the heavy deposit of iron-sulphid mixture. Photographed in August, 1911.

FIG. 2.—YELLOW NEWTOWN APPLE TWIGS.

Typical appearance of twigs developing from dormant-bud infections. A thick, powdery layer of summer spores is shown on the twig at the left. A patch of perithecia is shown at *p*. Photographed in July, 1911.

PREPARATION OF THE IRON-SULPHID MIXTURE.

The following directions are for the preparation of sufficient stock iron-sulphid mixture to make 500 gallons of spray: Fill a 50-gallon barrel about two-thirds full of water. Weigh out 10 pounds of iron sulphate (copperas), place in a sack, and suspend in the water. The iron sulphate will dissolve fairly rapidly, and when it is all in solution measure out carefully 2¼ gallons of commercial lime-sulphur solution testing 33° Baumé, or 2 gallons and 3 pints of a lime-sulphur solution testing 32° Baumé. Slowly pour all but 2 pints of the lime-sulphur solution into the iron-sulphate solution in the barrel, stirring the mixture vigorously with a hoe or shovel. The addition of the lime-sulphur solution will produce a bulky, black precipitate, and when all but 2 pints of the lime-sulphur solution has been added the mixture should be allowed to stand for a few minutes, when the black precipitate will begin to settle and a little of the clear liquid at the top can be carefully dipped out with a clean glass or cup. This clear liquid will probably show no yellow lime-sulphur color, which means that an excess of lime-sulphur solution has not yet been added. In other words, there is still some iron sulphate in solution, in which case the addition of a drop of lime-sulphur solution to the clear liquid in the glass will produce a black precipitate. This means that more lime-sulphur solution should be added to the stock in the barrel, and about half of the remaining 2 pints should now be poured in and the contents of the barrel stirred vigorously and allowed to stand. Some of the clear liquid should again be dipped off and tested as before, to determine whether an excess of lime-sulphur solution has been added. If necessary, the addition of small quantities of lime-sulphur solution should be continued until some of the clear liquid dipped from the top, after the contents of the barrel have been well stirred and allowed to settle, shows a pale yellowish lime-sulphur tint. The purpose of using a slight excess of the lime-sulphur solution is to insure all the iron sulphate being utilized. The voluminous black precipitate that is formed consists of iron sulphid, precipitated sulphur, and calcium sulphate. After a slight excess of lime-sulphur solution has been added, the barrel should be filled with water and the contents stirred thoroughly and allowed to stand for several hours. The black iron-sulphid mixture will settle into the lower half or third of the barrel, and the clear liquid should be poured off by carefully and gradually tipping the barrel, without allowing any of the black precipitate to run out. The barrel should again be filled with water, the contents thoroughly stirred and allowed to stand several hours, and the clear liquid poured off as before.

This operation of washing the precipitate should be repeated until the water poured off no longer shows the yellow lime-sulphur tinge. Probably three or more such washings will be required, depending upon how careful the operator has been in using only a slight excess of lime-sulphur solution.

It is evident that the preparation of this stock supply should be commenced two or three days before the spraying is to be done, but when once prepared it may be kept indefinitely. If care is used in weighing out each lot of iron sulphate and if the lime-sulphur solution used is accurately measured there will be no trouble in making up the stock supplies rapidly after the first two or three batches have been prepared, and it will be remembered that each batch is sufficient for making 500 gallons of spray mixture. In order to keep a supply of the stock mixture on hand, several batches should be prepared before the spraying commences, and as rapidly as a barrel is emptied the preparation of a new batch should be started. Iron sulphate is comparatively cheap, and the entire cost of materials for preparing 100 gallons of the mildew spray, when diluted according to the recommendations given in this bulletin, should not exceed 15 or 20 cents.

When the washing has been completed, the stock barrel should be filled with water to exactly 50 gallons. The material is now ready for use as directed under "General formula for the spray mixture," on page 17, but care should be taken to stir the contents of the barrel thoroughly each time before any of the mixture is taken out.

IMPORTANCE OF EARLY SPRAYING.

Attention has been called to the fact that the apple foliage is subject to mildew attack shortly after it begins to come out in the spring. The serious fruit dropping that may result from delaying the first application until after the fruit is an inch or more in diameter has been discussed, and attention has been called to the possibility of developing sulphur immunity or resistance to injurious sulphur effects by beginning the spraying early and repeating it at intervals of two to three weeks. Also, it has been stated that these sulphur sprays have a distinct stimulating effect on foliage growth and that the mildew is more readily controlled on vigorously growing trees. Thus there are a number of reasons for making the first spray application early in the season, namely, to protect the very early foliage from mildew, to develop immunity to sulphur injury and thus avoid serious fruit dropping later in the season, and to bring about sulphur stimulation, thus inducing a vigorous early growth of foliage. Furthermore, it has been found that precipitated sulphur acts as a restrainer of the arsenical foliage injury that in the Pajaro Valley

frequently results from the use of acid arsenate of lead applied after the early foliage has developed.

SPRAYING FOR APPLE SCAB.

Considering the climatic conditions of the Pajaro Valley, one might expect apple scab to become a serious disease of the fruit, and for that reason its relative absence is the more striking. Occasionally scab does considerable damage in scattered orchards, but in those in which the writers have carried on investigations in its control it has never been sufficiently abundant to make the experiments satisfactory. It is therefore not of sufficient importance in this district to require regular attention in spraying. Apple scab, in the degree in which it is present, is the only fungous disease of the fruit occurring in the Pajaro Valley.

GENERAL FORMULA FOR THE SPRAY MIXTURE.

Stock iron-sulphid mixture[1]	20 gallons.
Arsenicals and nicotine solution to be added	as required.
Water, to make	200 gallons.

When arsenicals and a nicotine solution are to be used in conjunction with the iron-sulphid mixture, the combined spray may be prepared by first running about 150 or 160 gallons of water into the spray tank. The agitator is then started and the 20 gallons of stock iron-sulphid mixture is poured in, after which the nicotine solution and the arsenicals may be added in the usual way. Sufficient water should then be added to make 200 gallons.

This same strength of iron-sulphid mixture, namely, 20 gallons in 200 gallons of spray, is to be used in all of the mildew applications. It will be seen that the 20 gallons of stock mixture used in each 200 gallons of spray contains the product from 4 pounds of iron sulphate. If commercial iron-sulphid preparations or other commercial products containing sulphur in very finely divided form are employed, they should be used in such quantities as to give the same sulphur content as the above amount of iron-sulphid mixture, or, better, the optimum dosage for mildew control should first be determined by experiments, since the fineness of the product will influence its effectiveness and therefore the amount to be used.

SPRAYING SCHEDULE.

The following spraying schedule for the control of apple powdery mildew has been worked out for the Pajaro Valley in particular, but

[1] See page 15, "Preparation of the iron-sulphid mixture."

it can undoubtedly be modified when necessary to meet the local requirements of other districts in which the disease may demand treatment. No recommendations regarding the use of insecticides are given, but it will be understood that the arsenicals and nicotine solutions which can safely be employed should be added in the proper amounts required for insect control at the various times when the mildew applications are made. This statement applies equally well to other districts than the Pajaro Valley. Several years of experimental and commercial spraying have demonstrated that the various arsenicals commonly employed, and also nicotine solutions, can be combined with the iron-sulphid mixture without affecting the insecticidal or fungicidal value of any of the materials.

FIRST APPLICATION.

The first application should be made at the time of and in conjunction with the first spraying for the control of the codling moth, and the combined spray, containing iron-sulphid mixture and the necessary insecticides, should be prepared as directed under "General formula for the spray mixture," on page 17.

The object in making this first application of the iron-sulphid mixture so early in the season is to develop sulphur immunity, which will lessen the danger of fruit and foliage dropping that might result from the subsequent sprayings, and to keep the early foliage protected from the mildew.

SECOND APPLICATION.

The second application should be made in conjunction with the second spraying for the control of the codling moth, and the kinds and amounts of insecticides regularly employed in this second codling-moth spraying should be added, as directed under "General formula for the spray mixture," on page 17.

In some apple-growing districts it may be found that on account of the rapid growth of the early foliage large numbers of mildew infections will become established on the leaves during the interval between the first and second sprayings. In that case it will undoubtedly be advisable to make an application of iron-sulphid mixture, 20 gallons of the stock mixture diluted to 200 gallons of spray, about 10 days after the petals fall. The sulphur stimulation of foliage growth resulting from these early sprayings is a very important factor in insuring vigorous foliage conditions later in the season. The writers have had opportunity to observe the decided improvement in foliage vigor on blocks that received these early treatments as compared with other portions of the same orchard that were not given the first spraying with iron-sulphid mixture until relatively late in the spring.

THIRD APPLICATION.

The third application should be made three weeks after the second, and the insecticide regularly employed at that time should be added to the spray mixture, as directed under "General formula for the spray mixture," on page 17.

FOURTH APPLICATION.

The fourth application should be made three weeks after the third, and the insecticides commonly employed at that time should be added to the spray mixture, as directed under "General formula for the spray mixture," on page 17.

SPRAYING METHODS.

In the spraying schedule here recommended it will be noted that the intervals between the applications are never greater than three weeks. In order to avoid any risk of causing sulphur injury in the form of fruit dropping it is very important that strict attention be given to the timing of the application, and, if necessary, the intervals should be made less rather than greater than three weeks. Obviously the weak dosage of iron-sulphid mixture recommended will not bring as marked and rapid mildew control as a stronger one would; but if the spraying is consistently and regularly done good results will surely be obtained, and it has been a noticeable fact that when a portion of an orchard is given this treatment for one year that portion, as compared with the remainder of the orchard, has shown decided improvement when the trees leaf out the following spring. Such an effect is probably partly physiologic and partly the result of mildew control, and its bearing on the general condition of the trees is evident.

Too much can not be said regarding the value and importance of thoroughness in spraying. A very large proportion of the men who handle the spray rods have, to say the least, a very inadequate conception of a satisfactory job of spraying, and when it is remembered that every leaf is susceptible of mildew attack, the importance of taking time to do a thorough job should be apparent.

Equipment is an important factor in good work. While practically all the spraying in the Pajaro Valley is done with power outfits it is entirely out of the question to spray a hundred-acre orchard with a single machine and finish the work in anything like schedule time. Attention has been called to the great number of twig infections in the upper parts of the trees, which means that care should be taken to spray the tops thoroughly. Spray rigs having towers are not used in the Pajaro Valley, and it has been necessary to depend upon long spray rods for reaching the tops of old

trees. This deficiency can be largely overcome by using angle nozzles of a type that throw a long, solid cone of driving spray. Such a type of nozzle is illustrated in figure 5. The writers wish to lay particular stress on using angle nozzles, which are so constructed as to throw the spray at an angle of 45° from the spray rod. Much more thorough work can be accomplished with such a nozzle, for by turning the rod it is possible to spray from below or above and from either side. Care should be taken to cover thoroughly the lower sides of the leaves, since that is where most of the mildew infections take place.

The spray deposit on the foliage protects the leaves from infection and kills out any patches of mildew that may be present. However, summer spraying is of comparatively little value in cleaning virulent twig infections, such as are shown in Plate IV, figures 1 and 2, and Plate VI, figure 2. This phase of the disease must be dealt with by another method, which will be discussed under "Pruning."

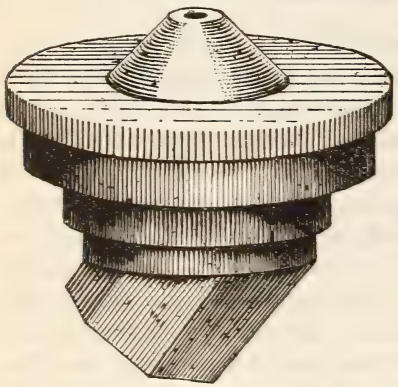

FIG. 5.—An excellent type of angle spray nozzle. The liquid enters the eddy chamber through an opening at the side and also through a hole in the center, directly under the orifice of the conical tip. By this construction a long, slender, solid cone of driving spray is produced.

WINTER SPRAYING FOR STIMULATION.

Two years of experimental work have demonstrated that winter spraying with fungicides is of no appreciable value in controlling apple powdery mildew. Attention has been called to the fact that the mildew attacks vigorous foliage much less severely than it does that which is puny and slow growing. In this connection the value of the foliage stimulation obtained from summer spraying has been pointed out, and it is evident that if a stimulation of vigorous spring growth can be brought about by a winter spray, just that much will be added to the success of the mildew treatment, as well as to the improvement of the general condition of the trees. As a matter of fact, it has been found that spraying during the dormant period with crude-oil emulsions, as commonly practiced in the Pajaro Valley for scale-insect control, will stimulate a vigorous early growth of foliage the following spring. Occasionally a few buds are injured by the oil, but material damage is very rarely noticeable.

PREPARATION OF CRUDE-OIL EMULSION.

Crude-oil emulsion, ready for applying, is prepared as follows:

Water	175 gallons.
Fish-oil soap	10 to 12 pounds.
Lye (caustic soda)	2 pounds.
California crude oil	25 gallons.

The materials are to be mixed in the spray tank in the order given and with the agitator in motion. The fish-oil soap should be dissolved in hot water before adding it to the 175 gallons of water in the tank, and for the first trial 10 pounds should be used. The required weight of lye may be added directly to the soap solution in the tank, allowing a few minutes for it to dissolve before pouring in the 25 gallons of crude oil. A light-brown emulsion should be formed as soon as the crude oil is added, and none of the oil should remain floating on the top of the mixture. Very little agitation is required to keep the oil emulsified, and the mixture is ready for immediate use. If the crude oil does not emulsify properly—that is, if some of the oil floats on the surface or if the mixture seems to contain small globules of oil—the preparation has not been successful. The trouble may be due to a lack of sufficient soap, in which case the remaining 2 pounds should be dissolved in hot water and poured into the tank. In some cases, when very hard water is used, a little extra lye may be required, and in rare cases it is necessary to use less than the 2 pounds. Occasionally a little difficulty is experienced in preparing the first tank of spray, but when the proportions of soap and lye are once determined there will be no trouble in making the emulsion.

It will be noted that the above formula gives a $12\frac{1}{2}$ per cent crude-oil emulsion. Such a mixture must be used only when the trees are entirely dormant, preferably during January. The spraying should be very thoroughly done, so as to produce a uniform, shiny, dark-brown coating over the entire surface of the twigs and branches. It may be well to repeat the statement that this winter spraying with crude-oil emulsion is not for the direct purpose of controlling the mildew, but is intended as a stimulant which will induce the production of vigorous early foliage, and this latter is of decided importance in mildew control.

Investigations that are still in progress seem to indicate that under some conditions dormant spraying with solutions of nitrate of soda plus caustic soda will be more desirable than crude-oil spraying.[1]

[1] Ballard, W. S., and Volck, W. H. Winter spraying with solutions of nitrate of soda. Journal of Agricultural Research, v. 1, no. 5, p. 437–444, pl. 50–51. 1914.

PRUNING.

The subject of pruning demands consideration because of its bearing on the problem of mildew control.

Attention has been called to the abundance of mildewed tips that can be seen during the dormant period. From the infested buds on these tips large numbers of seriously diseased shoots develop the following spring, and the question of eliminating them is a very important one, because on them are produced the enormous numbers of spores which serve to infect the healthy foliage as soon as it appears. Pruning offers the only practical solution of this problem, because, as has been stated, summer spraying is not effective in cases in which the entire twig and its leaves have become badly mildewed. The reason is that it is impossible to wet the entire mildew covering thoroughly, the spray collecting in drops, even when the operator is successful in wetting all parts of the shoot and its leaves. Particular attention should therefore be given to cutting out the mildewed tips, and that work should be made a part of the regular dormant-pruning operations.

It has been stated that trees that are growing vigorously and producing large, thrifty leaves are less seriously affected by mildew than poorly growing ones, even though they are of the same variety. One of the commonly recognized effects of winter pruning fruit trees is the improvement in growth and foliage conditions that result the following year. The apple is not an exception in this respect, and the improvement in vigor that can thus be obtained by pruning should be taken advantage of in combating the mildew.

To obtain the full benefits of winter pruning in the Pajaro Valley greater attention should be given to thinning out the trees. This should not be done by cutting out large framework limbs, but by pruning out far more brush than is ordinarily removed. Interlacing branches should be removed, and the current year's growth should be cut back one-third to one-half, or even more in the case of very young trees or very vigorously growing shoots. There is a tendency to allow the lower branches to become so long that they droop almost to the ground. It is true, as usually claimed, that the best fruit is borne on these lower branches, but that condition has been brought about largely by the fact that the tops of the trees have become badly affected by mildew or have lost their vigor through other causes. For these reasons it is important that the tops of the trees should be cut back as well as thinned out, so as to increase their vigor. The long spindling branches in the lower parts of the trees should be gradually shortened and the vigorous young twigs should be cut back so as to induce fruiting.

It will be understood that at the same time that this general pruning is being done very careful attention should be given to removing all mildewed tips. In fact, the pruning for mildew can be most conveniently done during the dormant period, because the grayish mildewed tips can be most easily seen when the foliage is off the trees. To do it thoroughly requires patience and very careful searching for the diseased tips, many of which are not more than an inch long and may occur on short lateral spurs. Even after the most careful work it will be found the following spring that some mildewed tips have been left and are sending out diseased shoots. These, however, can be removed with very little extra labor at the time the fruit is thinned. Even when no attempt is made to keep the mildewed tips cut out, it has been found that far less of them develop in orchards that are well sprayed and cared for than in those that are poorly sprayed and improperly cared for, and from these facts it should be seen that by giving careful attention to both pruning and spraying the number of mildewed tips can be reduced to a minimum.

It has been stated that in thinning out the trees large limbs should not be removed. Of course, there will necessarily be some exception to this rule, but in general, especially in the cases of the Yellow Bellflower and Yellow Newtown varieties, when limbs more than an inch and a half in diameter are cut off there is great danger that a serious wood-and-bark disease locally known as "sappy bark" will develop. This trouble appears at the wound and travels down the limb, eventually reaching the trunk and killing the tree. It causes a characteristic puffing and sloughing off of the bark, and the wood underneath becomes mushy. Disinfecting and painting the wounds have been found ineffective in preventing the disease, and when once started, cutting below the diseased portion does not eradicate it. The cause is unknown. Limbs an inch and a half or less in diameter can be removed without much danger of the disease appearing, and in winter pruning the heavy cutting should be confined as far as possible to that size or smaller.

In practicing the pruning methods outlined here, it might appear that a considerable proportion of the crop will be sacrificed by cutting out bearing wood. It is necessary to thin the fruit thoroughly almost every year, however, and the pruning will serve, in a measure, as a thinning operation. Moreover, the fruit will be found to size up better, especially after the system has been in use for two or three years.

It is true that a considerable annual expense will be incurred in keeping up the pruning of a large orchard of 20-year-old trees according to the plan outlined here. However, that expense will be greatest by far during the first year, when an extra-large quantity of mildewed tips and superfluous branches must be cut out.

If necessary, the work may be started on a part of the orchard and additional portions or rows included each year. Meantime close attention must be given to spraying.

CONCLUSIONS.

The orchards of the Pajaro Valley in California suffer more from apple powdery mildew than do those of any other large apple-producing district in the United States. The disease attacks the foliage and also the bark of the young twigs, but does not directly injure the fruit. It is therefore impossible to estimate the amount of commercial damage done, but since as much as 90 per cent of the foliage on trees of susceptible varieties may become diseased it is evident that such trees must eventually have their capacity for production lowered, either as a result of the vitality of the trees being reduced, or, more directly, because the annual growth and consequent increase in bearing surface is less than normal. The importance of giving proper attention to control measures is still further emphasized by the fact that the disease recurs regularly year after year and gradually acquires a stronger foothold if its progress is not checked.

The climatic conditions of the Pajaro Valley are peculiarly different from those of other large apple-growing sections, and their bearing on the general problem of mildew control may be summarized as follows:

(1) They are responsible for a peculiarly sensitive physiologic condition of the trees, (*a*) which is manifest in the extreme sensitiveness of the foliage and fruit to spray injury of one form or another, and (*b*) which appears to be evidenced by the pronounced susceptibility of the foliage to mildew attack.

(2) They influence directly the prevalence of the disease and the damage done by it, in that they furnish favorable conditions for the spread and development of the fungus.

(3) They supply conditions favorable to the breaking down of many compounds that are employed in spray mixtures and at the same time furnish conditions for the solution and the absorption of those decomposition products by the foliage. Thus, indirectly, the weather furnishes extreme conditions for the development of certain types of spray injury.

The fungus *Podosphaera leucotricha*, which causes apple powdery mildew in the Pajaro Valley, winters in the lateral and terminal buds of badly mildewed twigs. The shoots that develop during the following spring from these infected dormant buds soon become more or less covered with mildew, and spores are produced in enormous numbers. These spores give rise to the first infections of the healthy foliage. Therefore, one of the most important steps in the control of apple powdery mildew is the elimination of these early twig infections which develop from the diseased dormant buds. Cut-

ting out the mildewed twigs on which the infected buds are borne is the only successful method of dealing with this phase of the problem. Fortunately, this work can be done during the dormant season, for the grayish mildew covering remains on the diseased twigs, making them readily distinguishable from the healthy ones even after the leaves have fallen. The cutting out of the mildewed twigs should therefore be made an important part of the regular pruning operations.

Vigorous foliage is less susceptible to mildew attack than that which is puny and slow growing. One method of obtaining vigorous foliage is by winter pruning; hence, because of the value of vigorous foliage in the problem of mildew control, as well as for the betterment of the general condition of the trees, a more thorough system of pruning should be practiced in the Pajaro Valley. An increased vigor of foliage growth is also obtained by the spraying methods recommended in this bulletin.

Precipitated sulphur or sulphur in other extremely finely divided forms is the most satisfactory fungicide to use in foliage spraying for the control of apple powdery mildew.

In the Pajaro Valley several different effects may be obtained from spraying with such a finely divided form of sulphur, as follows:

(1) If the diseased areas are thoroughly covered with the spray mixture, the mildew will be killed out. A deposit of spray on the healthy foliage will prevent the establishment of new infections. As has been noted on a previous page, it is practically impossible, by spraying, to clean up satisfactorily those virulent cases of leaf and twig infection in which both the upper and lower surfaces of all the leaves, as well as the bark surface itself, become covered with mildew. The solution of this phase of the problem is in pruning out these mildewed twigs during the dormant season.

(2) Sulphur acts as a stimulant and induces the production of a vigorous growth of new foliage.

(3) Spraying with strong mixtures or allowing too long an interval to elapse between sprayings may, under Pajaro Valley conditions, result in serious foliage and fruit dropping, though in the East no such damage from sulphur spraying has thus far been reported.

(4) Spraying at frequent intervals with weak mixtures causes the tree to develop what the writers have termed an immunity to the damaging sulphur effects noted in the preceding paragraph.

(5) Finely divided sulphur in the spray mixture acts as a restrainer in reducing the tendency of zinc arsenite or acid arsenate of lead to produce the arsenical burning of foliage.

Winter spraying with crude-oil emulsion, as practiced in the Pajaro Valley at the present time, has been found effective in stimulating a vigorous growth of early foliage the following spring. Because of this stimulation, the use of crude-oil emulsion as a dormant spray offers valuable assistance in the general program of mildew control, for, as has been stated, vigorous foliage is less affected by the disease.

It is probable that investigations now in progress will show that in some cases dormant spraying with solutions of nitrate of soda plus caustic soda is more desirable than crude-oil spraying.

SUMMARY OF CONTROL METHODS.

By way of summarizing the above conclusions it may be stated that there are three distinct phases of the method of controlling apple powdery mildew as outlined in this bulletin:

(1) Foliage spraying with iron-sulphid mixture, precipitated sulphur, or sulphur in some other very finely divided form.

(2) Winter pruning of trees (*a*) for the purpose of obtaining the general stimulating effects that come from pruning at that time and (*b*) directed particularly toward the eradication of mildewed twigs.

(3) Winter spraying with some spray that has the effect of inducing a vigorous foliage growth in the spring.

The practice of careful and thorough summer spraying year after year will gradually bring about a much-improved condition of the trees, but for the best results the entire method, as outlined above, must be followed.

Finally, it will be remembered that the results, statements, and recommendations recorded in this bulletin are based chiefly on experiments and observations made in the Pajaro Valley, in California; and, because of the somewhat extreme conditions obtaining in that valley, it will probably be found desirable to vary the recommendations here given to suit the local conditions and requirements of other apple-growing districts in which the disease may become sufficiently prevalent to require attention. In some sections, for instance, summer spraying alone may provide a satisfactory control of the disease, and in certain districts it will probably be found possible to increase the amount of stock iron-sulphid mixture used to each 100 gallons of spray.

The various effects of sulphur which have been discussed, such as fruit and leaf dropping and stimulation of foliage growth, may not develop as strongly in other districts as they do in the Pajaro Valley, but before attempting to use very much stronger dosages of sulphur than those recommended in this bulletin careful consideration should be given to the possibility of causing sulphur burning on the fruit. In any case, it will probably be found necessary to repeat the mildew spraying at intervals of three weeks or less during the entire period in which the trees are putting out new foliage.