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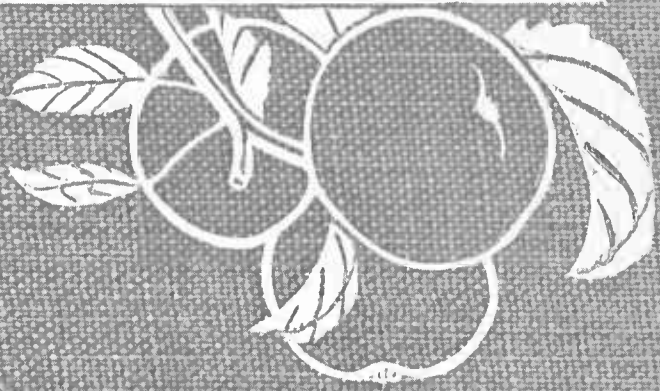
CONTROL OF APPLE POWDERY MILDEW



APPLE POWDERY MILDEW is a serious disease of nursery stock throughout the United States, and occasionally is serious on orchard trees in the East. In the apple-growing districts west of the Rocky Mountains, however, and especially in the Pacific Coast States, it has become an important orchard disease that annually causes heavy losses.

It is caused by a fungus that lives through the winter within the dormant buds and infects the new leaves, tender twigs, blossoms, and fruit in the spring.

Pruning out infected shoots during the dormant season is an important step in control, but this treatment must be supplemented by spraying during the growing season. The most effective sprays are diluted lime-sulphur solutions and those containing sulphur in a finely divided form.

This bulletin tells how to prepare the spray materials needed and how to apply them. A spraying schedule, showing concisely when and with what to spray, is included.

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief
Washington, D. C. May, 1920

CONTROL OF APPLE POWDERY MILDEW.[1]

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CONTENTS.

	Page.		Page.
Economic importance of apple powdery mildew	3	Control measures—Continued.	
Description of the disease	4	Spraying	8
Cause of the disease	6	Technic of spraying	9
Control measures	7	Time of spraying	10
Pruning	7	Spray materials	12
		Spraying schedule	13

ECONOMIC IMPORTANCE OF APPLE POWDERY MILDEW.

APPLE POWDERY MILDEW has long been recognized as a serious disease of nursery stock, but it was not until the development of an extensive apple-growing industry in the irrigated regions west of the Rocky Mountains that it attracted attention as an important orchard disease. It has been severe occasionally on old trees in the East, but in the important apple-growing districts of the Pacific Coast States it has become established and annually causes a heavy loss.

The disease frequently stunts the fruit and produces a disfiguring russeted appearance that greatly detracts from its market value. The chief loss, however, results from its attacks upon the foliage, which, in severe cases, so devitalizes the tree that it fails to produce fruit buds and causes a crop failure in the succeeding season.

The prevalence and severity of the disease in any season vary with the climatic conditions. When humid conditions prevail the spread of the disease is greatly facilitated, and it often assumes, if unchecked, epidemic proportions where it has become established. It is usually more common in the spring than during the summer, on account of the greater prevalence of rainy weather.

The disease is most important upon the apple, but also occurs on the pear, quince, hawthorn, cherry, plum, and juneberry. The commercial varieties of apple most susceptible to the disease are the Jonathan, Yellow Bellflower, Yellow Newtown, Esopus (*Spitzenberg*), Black Ben (*Black Ben Davis*), Grimes, and Rome Beauty. No variety is entirely immune, but the White Pearmain is the least susceptible and the Winesap is also resistant.

[1] This bulletin is of special interest to apple growers located west of the Rocky Mountains.

DESCRIPTION OF THE DISEASE.

The disease is found on the foliage, twigs, blossoms, and fruit of the apple.

Upon the affected leaves the disease is first manifested in small grayish or white feltlike patches of fungous growth. It usually appears first upon the under side of the leaves, which soon become crinkled and curled. When very young leaves are attacked they have a tendency to increase in length but not in breadth and may become somewhat folded longitudinally (fig. 1). The fungous patches rapidly enlarge and soon cover the entire leaf. In a very short time the affected areas are covered with masses of powdery spores, which give the disease its name and spread it about during the growing season. The affected foliage is rendered hard and brittle and is frequently killed. In any case it ceases to function normally, and a devitalization of the tree with consequent crop reduction results, the severity of which depends upon the proportion of the leaves attacked.

The tender twig growth may be infected independently, but is frequently attacked by the fungus spreading from attached leaves. Spores are produced on such twigs the same as on the leaves, and in addition another type, the ascospore, or winter spore, is produced upon the twigs. These winter spores are contained in the tiny globular black bodies that produce a speckled appearance in the felty fungous covering of affected twigs as early as the middle of June (fig. 2). The winter spores are no longer important in carrying the disease over winter, since the fungous threads penetrate and remain in the new buds which form on affected twigs. In the spring, when these infected buds open, the fungus resumes activity. The infection of twigs results in stunting or killing the parts affected, especially the terminal growth, which is particularly susceptible.

Blossom infection usually results from the overwintering of the fungus in the dormant blossom bud. In this case the entire blossom cluster, with attendant leaves, is attacked. The floral parts are shriveled and blighted, so that no fruit is produced (fig. 3). On account of the fact that infected buds do not open and spread mildew spores until some time after healthy buds have unfolded (usually about the time normal blossoms are dropping their petals), there is little danger of a general "blight" spreading over the blossoms during the blooming period.

The young fruits, however, are frequently attacked shortly after the blossoming period, and infections may remain established on the apples until the skin hardens in midsummer, after which the fungus generally does not persist upon the fruit. The fungus may become established upon the apples either by spore germination upon the

fruit or by spreading down the stem from infected twigs. In the former case it is usually the calyx end of the apple that is affected,

FIG. 1.—Branch of a Jonathan apple tree, showing three mildewed spurs. Note the curling and folding of the infected leaves on the central spur.

but in the latter the basin alone may be involved. When very young apples are infected their growth is stunted, but a russeting of the skin always results from the presence of the fungus (fig. 4). This

russeting shows a tracery of fine lines, usually as a network, but sometimes so closely woven that a solid patch appears. The expansion of the growing fruit frequently causes cracks to form in the hardened area and allows the apple to become shriveled (fig. 5).

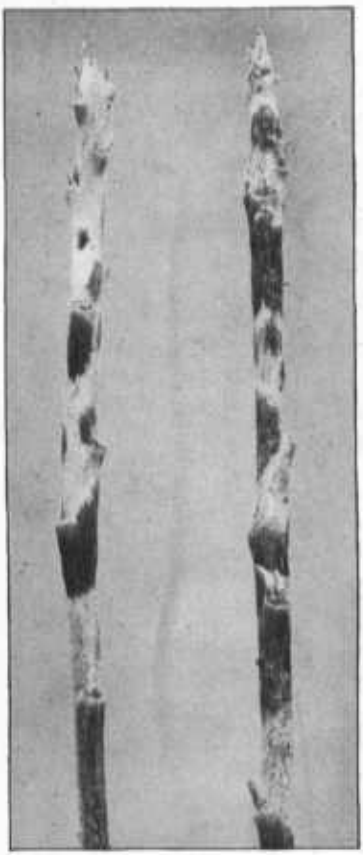

FIG. 2.—Mildew on dormant terminal shoots. Note the black patches of winter spores in the white fungous coating. The infected twig growth should be removed in the winter pruning, to assist in later control by spraying during the growing season.

CAUSE OF THE DISEASE.

Apple powdery mildew is caused by a fungus[1] which grows superficially upon the leaves, tender twigs, blossoms, and fruit of the apple. The feltlike covering of fungous threads over these parts sends down at frequent intervals tiny "suckers" to invade the cells of the host. These "suckers" extract the apple juices for the sustenance of the fungus. To propagate itself the fungus produces masses of spores in great profusion. These are wafted about by the wind. If one lodges upon tender growth where necessary moisture is present it will proceed to germinate and start a new infection.

This fungus has a very low moisture requirement for spore germination and therefore has adapted itself to growth in arid climates where other fungous diseases of the apple have not been able to persist. The occasional light rains in the spring are sufficient to give it a start, and the prevalence of dews during the growing season provides adequate moisture for it to continue to spread. With the increasing use of irrigation water and the increasing amount of transpiration from vegetation grown under irrigation the humidity of the air in these orchards has been increased. This, combined with the marked diurnal variation in temperature which characterizes such climates, brings dews nearly every night during the summer, and consequently conditions for the spread of mildew are becoming more favorable.

[1] *Podosphaera leucotricha* (E. and E.) Salm. *Podosphaera oxyacanthae* (DeC.) DeBary, a closely related organism, is occasionally found upon the apple in some parts of the eastern United States and produces effects very similar to *P. leucotricha*, but the latter is very much more prevalent, and it alone appears to be important as an apple disease.

CONTROL MEASURES.

Where it is necessary to spray for apple scab and where lime-sulphur or other sulphur sprays are used for this purpose, the scab treatment generally suffices for mildew control. Throughout the range of apple scab, therefore, mildew seldom requires special treatment. But in other localities, especially in arid regions, mildew must be treated independently.

Powdery mildew has been under investigation and experimental work on control measures has been carried on in such districts by the Office of Fruit-Disease Investigations since 1907. The recommendations for control made in this bulletin are based upon this work. During the early part of this period of investigation the work was carried on in the Pajaro Valley, Calif., where peculiar local conditions make the disease a most serious menace to the apple-growing industry and where local climatic influences necessitate special treatment to effect control.[1] Later work was carried on in the Wenatchee Valley, Wash., which is typical of the hot interior regions, where apple growing under irrigation has developed so extensively in recent years and where mildew control has become an important factor in successful orcharding.[2]

FIG. 3.—Mildewed blossom cluster from a Black Ben tree. Note the abundance of powdery spore masses over the leaves and blossoms and the deformity of the blossoms. Mildewed blossoms fail to produce fruit.

PRUNING.

In both of these investigations it was found important to remove the mildewed twigs in the winter pruning, thus eliminating sources of hold-over infection in the dormant buds and rendering much easier

[1] Ballard, W. S., and Volck, W. H. Apple powdery mildew and its control in the Pajaro Valley. U. S. Dept. Agr. Bul. 120, p. 26. 1914. Apple growers in regions of rainless, cool, and cloudy summers, but where ocean fogs frequently prevail are referred to this bulletin for control measures adapted to these peculiar conditions.

[2] Fisher, D. F. Apple powdery mildew and its control in the arid regions of the Pacific Northwest. U. S. Dept. Agr. Bul. 712, p. 28. 1918.

the control by spraying during the growing season. Mildewed shoots are easily detected during the dormant season by their gray or silvered appearance. Isolated infections which exist in scattered buds, however, make it impossible to control the disease by pruning alone. Cutting off infected shoots during the growing season and burning the prunings are also a help in establishing control, but in doing so spores are scattered and may spread the disease unless the trees are coated with a protective spray.

FIG. 4.—Mildew russeting of a Grimes apple. This blemish excludes infected apples from the highest market grades.

SPRAYING.

Finely divided sulphur, such as that prepared by precipitating iron-sulphate solution with lime-sulphur[1] or as found in various commercial sulphur pastes, is a most effective control agent against apple powdery mildew. It is especially valuable as a protective spray, but is less efficient against existing infections owing to the difficulty of thoroughly covering the mildew growth. Lime-sulphur solution is much more effective against active mildew, by its caustic properties immediately destroying all fungous growth with which it comes in contact. It likewise forms an excellent protective spray and is to be preferred where it may be safely employed, especially where pruning has not greatly reduced the number of hold-over infections. Copper sprays are less effective against mildew than the sulphur sprays and are also more expensive. Their use is only advisable during the period of hot burning sunlight in the interior regions, when the application of sulphur in any form results in

FIG. 5.—Jonathan apple, showing mildew infection with resulting cracks formed in the russeted area, causing the apple to shrivel.

[1] For directions for the preparation and dilution of spray materials, see pp. 12–13.

severe burning of the fruit (fig. 6). Of the copper sprays, either neutral Bordeaux mixture,[1] sal soda-Bordeaux mixture,[1] or ammoniacal copper carbonate[1] is preferable because it does not stain the fruit.

TECHNIC OF SPRAYING.

The technic of spraying for mildew is important. Since it is largely a foliage disease, and since a single infected leaf may produce enough spores to infect many trees if proper conditions prevail, it is important to cover every leaf. If the leaves are thoroughly

FIG. 6.—Pryor Red apple, showing "sulphur sunburn," the type of injury that invariably follows the application of sulphur in any form after the advent of intense sunlight in the interior irrigated apple-growing districts.

sprayed the twigs and fruit will be properly covered at the same time. Attention should therefore be centered on thoroughly wetting the foliage. In this connection the wetting power of the sprays is very important. Lime-sulphur possesses the best wetting power of any of the sprays ordinarily used, but even with this material there is a tendency for it to form in drops, leaving unprotected areas between. The use of a "spreader" is advisable with any of the sprays that may be used. Among the most economical and effective spreaders are casein[2] and saponin.[2]

Any spray machinery or apparatus is efficient against mildew if it will drive the spray in a fine mist through the tops of the trees.

[1] For directions for the preparation and dilution of spray materials, see pp. 12–13.
[2] For directions for preparation, see p. 13.

A pressure of at least 200 pounds is necessary for this, and 250 pounds is desirable. Nozzles of the eddy-chamber or whirlpool type have proved most efficient. With large trees it is advisable to station one man upon the tank or a tower to cover the tops of the trees, while another follows upon the ground to cover the lower branches and the inside. Special attention should be given the terminals and the under surfaces of the leaves.

TIME OF SPRAYING.

The first application should be made when the cluster buds have separated, but before full bloom (fig. 7). This is commonly called the "cluster bud" or "pink" spray. It protects the early foliage and the blossoms and hardens tender varieties so that they are less subject to injury from the following applications.

FIG. 7.—Cluster of apple buds at the right stage for the first mildew spray.

The second application, or "calyx spray," should be applied as soon as most of the petals have fallen (fig. 8). Lime-sulphur solution may be combined with the arsenical used at this time for codling-moth control. This spray is very important in mildew control and should not be omitted. It is designed to destroy new infections and provide protection to the rapidly expanding healthy foliage as well as to the young fruit. On certain varieties of apples, notably the Stayman Winesap, the dropping of the fruit and foliage without any sign of injury sometimes follows the application of sulphur materials at this period, particularly if accompanied by humid weather conditions. This is especially true if the "pink" spray has been omitted. Early and frequent application of sulphur sprays is important in developing "sulphur immunity"[1] and in avoiding this injury.

[1] Ballard, W. S., and Volck, W. H. Loc. cit.

A sulphur spray should again be applied about two weeks later. In the hot interior districts this constitutes the latest time at which sulphur materials may ordinarily be used without danger of injuring the fruit exposed on the south side of the trees. It has been found that such injury, or "sulphur sunburn" (fig. 6), invariably follows the application of sulphur in any form in the hot districts

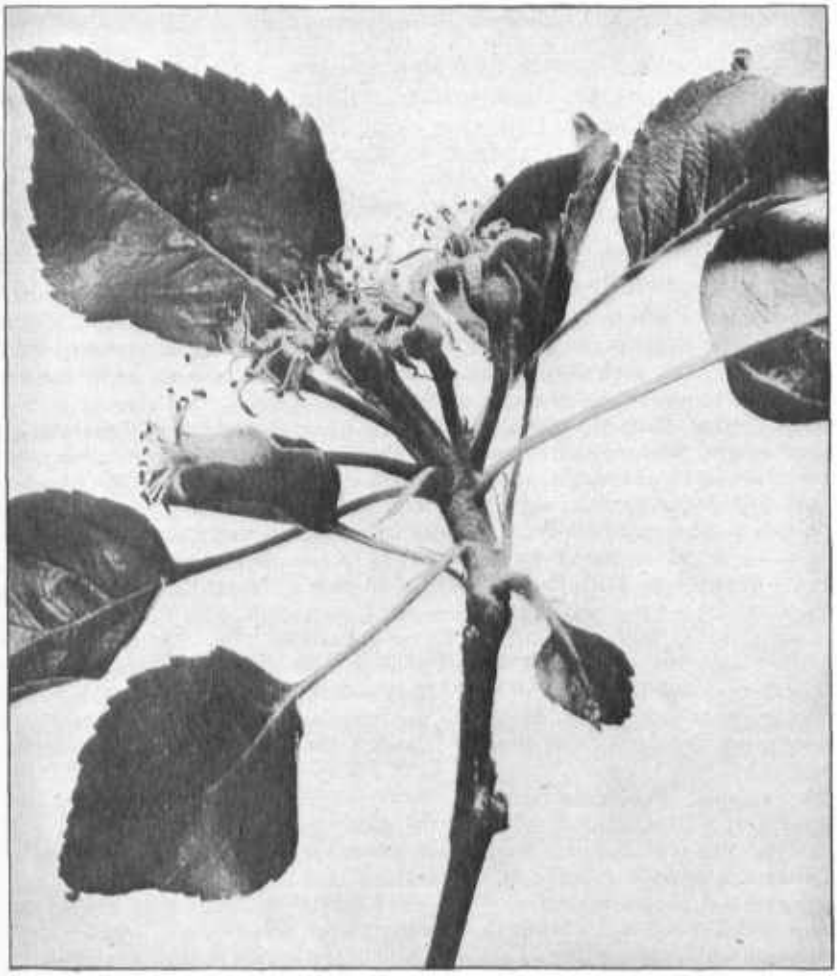

FIG. 8.—Cluster of young apples with the petals shed, the right stage for the second mildew spray and the first codling-moth treatment.

when shade temperatures of 90° F. or more are experienced within two weeks of the time of spraying. In these districts foliage burning is usually of minor importance.

The fourth application should follow within two or three weeks and at the time of the second spraying for codling-moth control. If mildew continues very serious in the orchard, sulphur materials

must be used for effective control and are to be recommended in any case where the fruit crop is light. Otherwise one of the copper sprays may be used.

Later spraying at intervals of two or three weeks until the latter part of August is recommended where the disease has become established. This is important to insure sufficient healthy vigorous foliage to allow the formation of fruit buds and in the prevention of dormant bud infection.

Maintaining a vigorous growth condition is an important factor in rendering trees more resistant to mildew attacks. Proper attention to cultivation, fertilization, and irrigation therefore has an important bearing upon mildew control.

SPRAY MATERIALS.

The preparation of the more important spray materials for orchard use is outlined below.

Lime-sulphur solution.—Use the ordinary commercial concentrate at a dilution of 1 to 50. Greater strength adds no benefit in mildew control, while weaker strengths, even to a dilution of 1 to 100 will cause as much damage in burning exposed fruit in hot weather.

Iron sulphid, Ballard and Volck formula.—(For use where soluble sulphids cause serious injury, i. e., climatic conditions characterized by rainless, cool, and cloudy summer weather, with frequent heavy fogs that drench the foliage.) Dissolve 10 pounds of iron sulphate in a barrel containing 50 gallons of water. Add lime-sulphur solution until no more precipitate forms. Allow the precipitate to settle and drain off the clear liquid. Again fill the barrel with water, stir the precipitate, and allow to settle, and then drain off the clear liquid as before. Continue this washing process until the yellow color disappears from the clear liquid. Make up to 50 gallons for a stock solution. For spraying, stir the stock solution well, and dilute 10 gallons in 90 gallons of water to make 100 gallons of spray.

Under conditions prevailing in the hot interior regions this material will cause severe fruit injury or sulphur sunburn, the same as any other sulphur material.

Iron sulphid, Wenatchee formula.—Slowly add 2 pounds of granulated iron sulphate to 100 gallons of water in the spray tank, keeping the liquid well agitated. The iron sulphate goes into solution very quickly. Add 3 quarts of lime-sulphur solution (testing 34° Baumé) and use immediately.

Ammoniacal copper carbonate.—Dissolve 5 ounces of commercial copper carbonate (malachite) in 3 pints of ammonia (25 per cent solution, which should be diluted before using). First make a paste of the copper carbonate and water. Slowly add the diluted ammonia and stir well. Dilute to 50 gallons in the spray tank. Or proceed as follows in the preparation of modified eau celeste, which contains ammoniacal copper carbonate: Dissolve separately in water 2½ pounds of sal soda and 2 pounds of bluestone (in a wooden vessel). Add the resulting solutions to water in the spray tank and, with agitation, add 1 quart of 26 per cent ammonia, and finally make up to 50 gallons.

Neutral Bordeaux mixture.—Dissolve 4 pounds of bluestone in water in a wooden vessel and add to nearly 50 gallons of water in the spray tank. From a stock solution of lime, prepared by slaking a quantity of fresh stone lime in water, slowly add, with agitation, a small quantity at a time until the spray

solution is neutral and make up to 50 gallons. The neutral point is reached when a red color is no longer produced by the addition of a few drops of a potassium ferrocyanid test solution. The latter is prepared by dissolving a small quantity of the chemical in a bottle of water.

Sal soda-Bordeaux mixture with lime (Burgundy mixture with lime).—Dissolve separately in water 4 pounds of bluestone (in a wooden vessel), 5 pounds of sal soda, and 2 pounds of lime. Add, with agitation and in the order given, to water in the spray tank, and make up to 50 gallons for use.

Casein.—Use ordinary commercial casein at the rate of 4 ounces to 200 gallons of spray. The casein must first be put into solution, and this is best accomplished by heating to the boiling point for about 10 or 15 minutes in water to which has been added one-seventh as much sodium hydroxid as casein used. In this manner a stock solution may be prepared and a proportionate quantity taken for use with each tank.

Saponin.—Prepared by making an infusion of soaptree bark and water. Soaptree bark may be had cheaply at most drug stores in 2-ounce packages. Add the contents of one of these packages to a quart of water and boil for 15 minutes. Strain and use the clear solution for 200 gallons of spray. Several infusions may be prepared from the same material, but it gradually loses strength.

Stock solutions.—If a considerable quantity of any of the above sprays is to be used it will be found convenient to prepare stock solutions in advance of the spraying operations. This may be done by dissolving a given quantity of the material in a measured quantity of water. For example, in preparing a stock solution of bluestone, proceed as follows: Weigh 50 pounds of bluestone, and suspend it in a clean gunny sack near the top of a barrel containing 50 gallons of water (the bluestone will dissolve over night). If the resulting solution is well stirred, each gallon removed will contain 1 pound of bluestone.

SPRAYING SCHEDULE.

In order that the apple grower may have before him in a concise form the recommendations for spraying against mildew offered in this bulletin, a condensed spraying schedule is given (Table I).

TABLE I.—*Spraying schedule for the control of apple powdery mildew.*

Application and time.	Materials.
First mildew spray ("pink spray"). Apply just before the blossoms open. (Fig. 7.)	Lime-sulphur, 1 to 50; or iron sulphid.
Second mildew spray (calyx spray). Apply as soon as most of the petals have fallen.[1] (Fig. 8.)	**Lime-sulphur**, 1 to 50; or iron sulphid.
Third mildew spray. Apply about two weeks after the calyx spray.	Do.
Fourth mildew spray. Apply about four weeks after the calyx spray.[1]	Lime-sulphur, 1 to 50, or iron sulphid;[2] or ammoniacal copper carbonate; or neutral Bordeaux mixture;[3] or sal soda-Bordeaux mixture.
Later sprays. Apply if necessary at intervals of about three weeks until the latter part of August.	Do.

[1] An arsenical for the control of the codling moth should be added to the second and fourth applications.
[2] Use if the infection is severe or if the crop is light.
[3] Use where the danger of burning the fruit is to be avoided.

The more important applications as well as the preferred spray materials shown in Table I are printed in boldface type. To insure

maximum control the first four sprays should always be applied. It is believed that a consistent spraying program involving the use of these four applications will suffice in most cases and in ordinary seasons; but in orchards where mildew has become established it will be necessary to continue spraying throughout the growing season until the disease is brought under control.

Experience in the orchards of the Northwestern States has shown that apple powdery mildew is cumulative in its effects, gradually becoming more severe if not brought under control. The effects of spraying have also been shown to be cumulative, as it has been found impossible to eliminate the disease entirely or even greatly reduce it with any one spraying alone; but a season's consistent effort in spraying has always brought marked results in the way of control.

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