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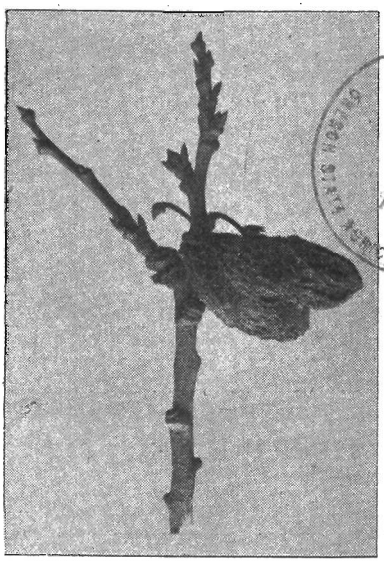
BULLETIN No. 57. APRIL, 1899.

Department of Entomology and Plant Diseases.

OREGON AGRICULTURAL EXPERIMENT STATION.

CORVALLIS, OREGON.



BROWN ROT.

A. B. CORDLEY.

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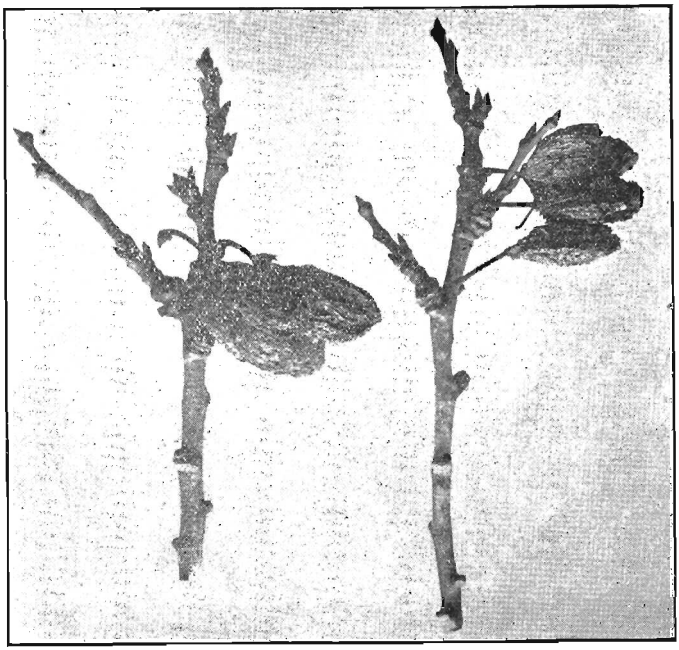

Plate I. Fig. 1—"Winter Mummies."

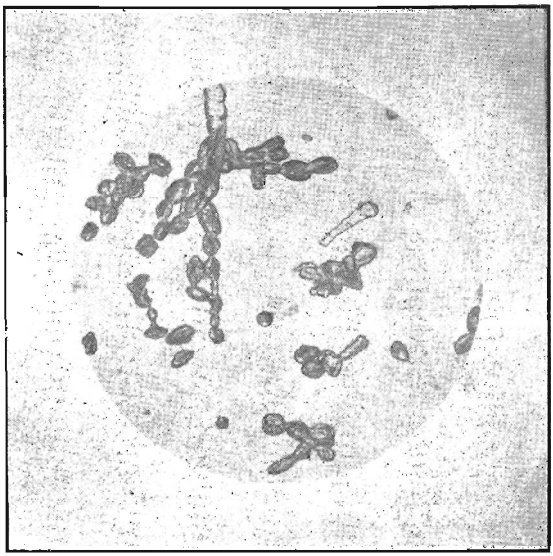

Fig. 2—Spores highly magnified.

BROWN ROT.

(*Monilia fructigena, Pers.*)

GENERAL CONSIDERATIONS.

IN the fall of 1895, a few diseased prunes were received at this station, which were determined by Professor Hedrick and myself to be infested with the fungus of brown rot, *Monilia fructigena, Pers.* Subsequent inquiry developed the fact that in the infested area nearly the entire product of several orchards had been destroyed, and that in all probability the pest had been present in the state for several years.

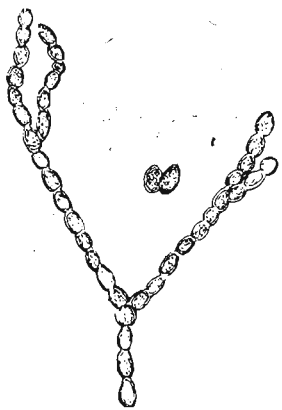

Fig. 1. Showing bead-like arrangement of spores × 300.

At the time a brief statement of the presence of the disease was made through the columns of the press and in Press Bulletin No. 5. So far as we have been able to determine these were the first published notices our fruit growers had received of the presence and nature of this destructive pest, although Dr. Galloway had perhaps intimated its presence, in the statement that it prevails throughout the country and that the losses resulting from its attacks are frequently very great.*

A short article on the subject was prepared by Professor Hedrick for Bulletin No. 45 of this station, and in the fall of 1897 the disease suddenly became so exceedingly destructive over a large portion of western Oregon, and so many theories were advanced to account for the serious and unusual injury, that I prepared for the "Rural Northwest" a short account of the disease and of methods to be employed in combatting it. This paper, with slight changes, has recently been reprinted in the Biennial Report of the State Board of Horticulture. Prune growing has become one of the important industries of the state, and since brown rot is one of the most dangerous

* Rept. U. S. Dept. of Agriculture, 1888.

diseases of the prune, and since none of the above sources of information, except the last, are now available, this bulletin is issued with the hope that it may prove of interest and of value to the prune growers of the state.

Although Brown Rot has attracted general attention in this state only within the last few years, it is by no means a new and unheard-of pest. Twenty years ago Von Thumen wrote that it is the most widely distributed and perhaps the most noxious of all diseases that occur on fruit. From the more recent writings of European authorities we may infer that the disease is not so destructive on the continent, as the above statement would lead us to believe, and it is possible that from this fact we may hope that in the future the disease may lose somewhat of its virulence in this country. Sorauer merely mentions *Monilia fructigena;** Frank treats of the disease somewhat fully but does not mention its excessive destructiveness;† Prillieux describes the disease but states that it is not so serious as in the United States;‡ and Tubeuf and Smith briefly refer to it as common in Britain and the United States.§

Fig. 2.
Spores × 300

In this country Von Thumen's statement has been abundantly verified. Smith states that this fungus is more common and far more destructive than any other observed on the peach. He estimated that in 1888 fully 800,000 baskets of peaches were destroyed on the Delaware-Chesapeake peninsula, and that in 1889 the crop was fully 500,000 baskets short on account of the blighting of the blossoms by *Monilia*. In Georgia and the far south the loss is sometimes as much as two-thirds of the whole crop. Taft states that in Michigan some seasons a large part of the crop of peaches, cherries and plums is destroyed. Garman has reported serious rotting of apples in Kentucky as due to *Monilia*, and many other instances of destructive attacks could be mentioned.

In this state the disease has attracted attention chiefly on account of the excessive rotting of prunes in the fall of 1897, and of a similar but less serious injury in the fall of 1898. During the latter period, however, we saw badly infested peaches on sale here at Corvallis

* Pflanzen-Krankheiten, 1886.
† Krankheiten der Pflanzen, 1896.
‡ Maladies de Plantes, 1897.
§ Diseases of Plants, 1897.

and received samples of such fruit from Salem and from Roseburg. Recently Mr. Joe. E. Harvey of Roseburg has written me that brown rot has been observed upon peaches in that vicinity during the past four years. At first it attacked the Alexander and other early varieties and did but little damage, but during the past two years it has grown rapidly worse and has spread to other varieties to such an extent as to cause general alarm. Mr. J. R. Casey of Ashland, member of the State Board of Horticulture for the Third Horticultural District, has informed me that the disease is present in southern Oregon where, however, it causes but little loss on account of the uni form lack of moisture at the time the fruit is ripening.

Fig. 3. Germinating spores × 300.

WHAT IS BROWN ROT?

The name which we have selected as the title of this article is not particularly characteristic of the disease under consideration. Many, perhaps most of the fungi and bacteria which induce decay in fruits are accompanied by a browning of the tissues, and hence might with equal propriety be designated as the "brown rot." The disease to which we particularly refer is variously described as brown rot, ripe rot of plums, fruit rot, plum fruit rot, brown rot of stone fruits, plum rot, peach rot and blight, quince rot, etc., the common name selected depending somewhat upon the fruit or other portion of the plant attacked, but more upon the individual choice of the author. "Brown Rot" characterizes the disease perhaps as well as any of the other names and has the advantage that it is the one by which it is known by our fruit growers. Whatever common name may be applied to the disease, and upon whatever fruit or other portion of the plant it may occur, the cause of the disease—the fungus—is the same, *Monilia fructigena, Pers.*

APPEARANCE OF THE FUNGUS.

Wherever it occurs the presence of this fungus is shown by the production of clusters of ash-grey spores on the surface of the diseased tissues. In passing through almost any of our prune orchards when the green fruit is being picked, or even earlier, one may see here and there a prune that is partly or wholly covered with this ash-grey or blue-grey "mold." Occasionally several such speci-

mens may be seen hanging together in a cluster. If one of these "moldy" prunes be examined it may be observed that the "mold" occurs in clusters which are frequently arranged in more or less definite, concentric circles, although this arrangement is not so well marked upon the prune as upon certain other fruits. By the use of a small hand lens one may determine that each of these clusters consists of immense numbers of minute thread-like projections which have burst through the epidermis. If a little of this mold be taken from the fruit and examined with a higher power of the microscope, it may be seen that each of these minute projections is composed of a number of very small oval bodies joined end to end like a string of oval beads. (See Fig. 1.)

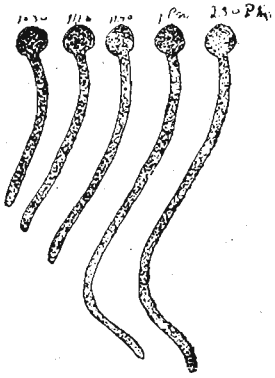

Fig. 4. Spore mounted at 7 a. m. and showing growth of germ-tube to 2:30 p. m. × 300.

THE SPORES.

These minute bead-like bodies are the spores or "seeds" of the fungus, and every infested fruit is capable of producing hundreds of thousands of them. Each spore is exceedingly minute. It is composed of a single cell and is nearly colorless. The shape is generally oval, but both shape and size vary somewhat. (See Fig. 2, and Fig. 2, Pl. 1.)

If some of these spores are placed in a perfectly dry place and examined from time to time, it may be noted that they will remain for an indefinite time apparently unchanged. We have examined such spores that had remained for nearly two years without germinating—so long in fact that they had lost the power to germinate, as was determined by numerous tests. If other fresh spores are placed in fruit juice, or otherwise supplied with moisture, and kept in a moderately warm atmosphere, it will be observed that in a very short time (two hours or less) each spore will commence to push out a delicate germ-tube. In other words, the spores will "sprout," and if kept under favorable conditions the germ-tubes will grow so rapidly that in from 24 to 48 hours they will in turn develop spores. We may thus prove that heat and moisture are both essential to the development of the fungus of brown rot. Fig. 3 illustrates spores that are just beginning to germinate. Figs 4, 5 and 6 illustrate the development of the germ-tube and the rapidity of its growth. Fig.

7 shows a spore which was germinated and which produced spores in distilled water.

THE MYCELIUM.

Grown under more nearly normal conditions, the germ-tube is much shorter and somewhat thicker than is shown in Fig. 7, and is much more branched. It is the germ-tube which by continued growth becomes the mycelium of the fungus—the vegetative portion—which penetrates the tissues of its host, and under the influence of which the latter assumes the characteristic appearance of brown rot. This mycelium bears the same relation to the whole fungus that the roots, stem, branches and leaves of a higher plant do to the entire plant. It is the portion which absorbs food materials and assimilates them, and which eventually produces the reproductive bodies or spores.

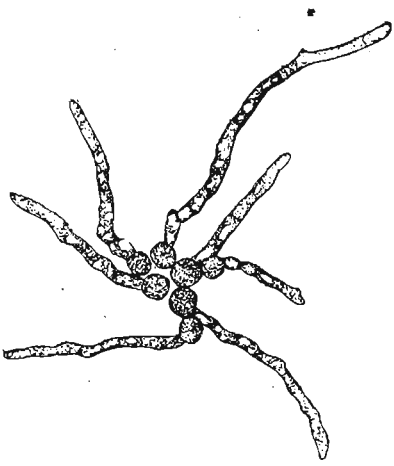

Fig. 5. Group of spores showing growth of germ-tube at 14 hrs. × 300.

The spores are produced in immense numbers and are so small and light that they are blown about by the wind, washed about by the rains and carried about by birds, insects and other agencies. Should they chance to fall upon the surface of flower, leaf or fruit, in the presence of moisture and a sufficiently high temperature, the spores will germinate, the germ-tube will penetrate the epidermis and the mycelium will ramify through the underlying tissues absorbing nourishment and inducing those changes which we call brown rot.

Many writers have denied that the germ-tube has the power to penetrate the uninjured epidermal tissues, maintaining that this must be ruptured by other causes. In view, however, of the results of numerous experiments, there can now be little doubt that under favorable conditions the germ-tube has this power. Arthur produced the disease in cherry leaves and blossoms by simply sowing them with spores and keeping them in a moist-chamber. Smith

has infected the soundest peaches by merely sowing a few *Monilia* spores in a drop of water upon their surface. July 1, 1895, I placed several perfectly sound cherries and plums in a moist-chamber and sowed a few spores in drops of water upon their uninjured surfaces. July 3d these spots were slightly discolored, and by the 4th spore clusters had formed on both the cherries and the plums.

While it is evident from the above tests that the germ-tube has the power to penetrate the epidermis of flower, leaf or fruit when in the presence of sufficient moisture, we have noticed that the disease rarely does attack an uninjured prune until the ripening process is well under way. This is probably due not alone to the resistant epidermis of the green Italian prune, but also to the small amount of moisture in the atmosphere during the summer months. Observations during the past two seasons have shown that in nearly every instance, prunes which are infested with *Monilia* early in the season have first been attacked and the epidermis broken by the larvæ of the peach twig-borer, *Anarsia lineatella* Zell. It is these injured prunes which develop the spores with which later in the season the ripening crop is infected. If they were gathered and destroyed from time to time as the rot developed, it would undoubtedly aid materially in checking the spread of the disease.

BLIGHTING OF BLOSSOMS.

Upon peaches and cherries the fungus usually makes its first appearance in spring upon the flowers about the time the petals fall. Galloway states that at first a slight discoloration appears at a given point. This rapidly increases in size until at length the entire blossom assumes a brownish hue. After killing the flower the fungus frequently attacks the pedicle where it produces similar discolorations to those described above. The dead flowers usually remain on the tree for three or four weeks, then, if the weather is wet, they begin falling, and as they consist at this time of a soft mass of rotten tissue, they stick to any part of the tree with which they come in contact. Careful experiments have shown that these rotting flowers are highly infectious and that wherever they touch the leaves or fruit decay sets in. We have never observed this blighting of the blossoms of prunes, and do not know that it occurs, although it is possible that the excessive blighting in the spring of 1896, which was attributed to the unusual rainfall, may have been due to *Monilia*, which would certainly have flourished under conditions which then prevailed.

BLIGHTING OF TWIGS.

In the peach, the blossoms of which have very short pedicles, the blight does not stop with the destruction of the flower, but the mycelium of the fungus may extend through the pedicle into the tissues of the twig. The portion of the twig thus attacked soon assumes the characteristic leathery brown color of brown rot. The extent of the tissue thus involved usually varies with the conditions of heat and moisture, but should it extend around the twig so that the latter is girdled, all of the terminal portion beyond the point of infection will blight. This twig blight of the peach occurs not only in spring when the mycelium enters the twig through the pedicles of the blighted blossoms, but it also occurs in fall, when it enters through the pedicles of rotting peaches, which have been allowed to remain on the trees. This twig blight of the peach, which is due to *Monilia*, should be distinguished from the blight which occurs in spring as a result of the attacks of the larvæ of the peach twig-borer, which is occasionally quite general. Blight of prune twigs is frequently caused by this insect, but I have never observed it to result from an attack of Monilia.

Fig. 6. Two of the spores shown in Fig. 5, showing germ-tube at 17 hours, × 300.

ROTTING OF THE FRUIT.

The appearance of brown rot upon the fruit varies somewhat with the variety attacked. On cherries and peaches a small circular brown spot appears at the point of infection, and this rapidly spreads until the whole fruit becomes shrunken soft and discolored. As the disease spreads the surface of the diseased tissues becomes covered with the characteristic ash-grey conidial tufts. In apples, pears, and quinces the disease spreads in much the same way but more slowly, and usually with a less abundant spore formation. In prunes the disease may effect the entire fruit and still produce but little external evidence of its presence. Prunes apparently sound, when opened may exhibit a brownish rotten appearance due to the

work of the fungus. We have seen many bushels of prunes taken into the warehouse at night in an apparently healthy condition, which the following morning were well covered with the conidial tufts of *Monilia*, and many of these prunes which did not show such tufts and were placed in the drier under the impression that they were in good condition, failed to produce a good quality of dried fruit. About the first external evidence of brown rot in the Italian prune is the presence of the conidial tufts and these do not develop freely unless in a warm moist atmosphere.

BROWN ROT AND ORCHARD CONDITIONS.

We have hitherto considered brown rot largely from the laboratory standpoint. Let us now examine the same facts in their relation to orchard conditions.

During the dry summer months, although the spores may be and probably are present, the disease does not spread rapidly because the spores do not readily germinate under the conditions which then prevail. But here and there the skin of a prune becomes broken allowing the spores free access to the moist interior. Thus it is that we have the occasional "moldy" prune to which we have previously referred as being present during the time of green fruit shipments. Through the agency of winds, insects, etc., the almost innumerable spores produced on these early infected fruits are constantly being distributed to other fruits. In the absence of moisture myriads of these spores fail to germinate and if these conditions unfavorable to germination should prevail throughout the ripening period and while the fruit is being gathered, little or no damage would be done by brown rot.

But it oftens rains during this period; and even though it does not rain, there are many days when the air is highly charged with moisture. If at the same time the temperature is sufficiently warm the conditions for the germination of the spores are almost perfect and the disease spreads with exceeding rapidity.

WHERE THE FUNGUS PASSES THE WINTER.

Considerable of the rotting fruit was left in the orchards last fall and may now be seen hanging to the trees and lying upon the ground. Fig. I, Pl. I, shows some of these "winter mummies," which were taken from an orchard in this vicinity late in February. In another orchard we discovered several bushels of rotted fruit

which had been culled from that sent to the drier and instead of being destroyed had been dumped upon the ground in the orchard. Countless millions of spores were present upon this fruit, and there is abundant evidence that such winter spores will retain their vitality until spring. In addition to these spores which were developed in the fall, and which, as stated, retain their vitality until the following spring, the fungus has another method of surviving the winter. Smith has shown that the mycelium which ramifies through and through the tissues of the fruit, disintegrating the cells and causing rot, may remain dormant throughout the winter in the "winter mummies," and with the advent of warm moist weather in spring, will again push forth an abundant crop of spores. Humphrey and Chester have demonstrated the presence in these "winter mummies" of certain thick walled moniliform threads and single cells which they consider to be resistant resting spores which further insure the survival of the fungus through the winter. Should the weather conditions be favorable for the germination of the spring crop of spores at the time the trees are in bloom, these spores may be the cause of a more or less serious blighting of the blossoms, and even of the young tender shoots of the peach, but whether this occurs or not, the spores will be present to infest the fruit when-

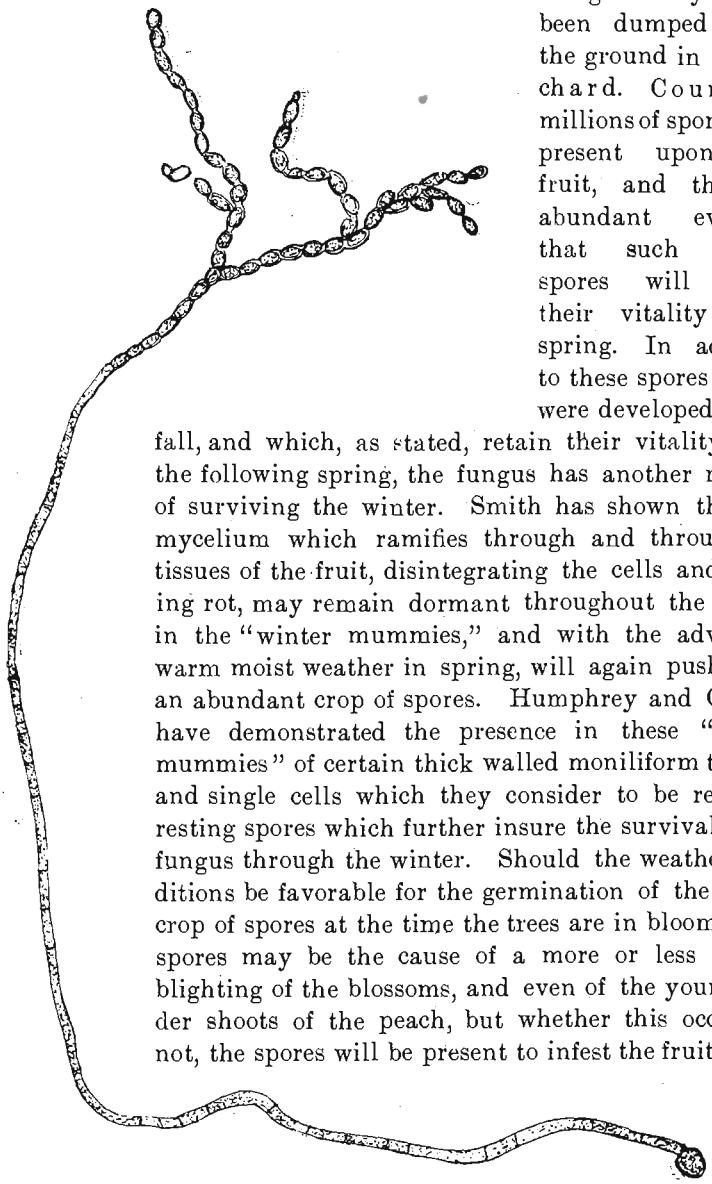

Fig. 7. Group of spores grown from single spore in distilled water × 300.

ever the conditions of heat and moisture do become favorable.

REMEDIES.

This disease is one of those by which the prune grower is forced "to prove his faith by his works." It spreads so rapidly when the conditions are favorable that it is nearly useless to attempt its control under such conditions. All methods must be preventive. And yet a grower may almost be excused, for hesitating to apply somewhat expensive preventive measures for the purpose of controlling a disease that may not cause any serious loss for several years on account of lack of favorable weather conditions. Now that the disease is well established, however, any prune or peach grower who fails to employ preventive measures deliberately takes the chance of losing a large proportion of his crop by brown rot, even though such loss may not occur every year. Preventive measures are in the nature of insurance.

Since so far as is known at present the fungus passes the winter only in the mummies which remain hanging to the trees or lying upon the ground, the first method of preventing the disease which presents itself is to destroy these mummies. Not a single one should be allowed to remain in the orchard over winter. All should be gathered and completely destroyed. This is the least expensive and perhaps the most important step in preventing brown rot. It should, however, be supplemented by spraying. This station has under way extensive experiments in spraying prunes for brown rot and it is hoped that by another season sufficient data will have accumulated to enable us to outline definitely the best methods to be pursued in this locality. Chester, of the Deleware station, has conducted the most careful and extensive experiments along this line, and, as a result of three year's work, he recommends that

(1) Very early in the spring it will be well to spray the trees thoroughly with a solution of copper sulphate, one pound to twenty-five gallons of water.

(2) When the fruit buds begin to swell spray either with the acetate of copper solution or the Bordeaux mixture.

(3) Just before the first buds open repeat the latter.

(4) When the bloom begins to shed spray with Bordeaux mixture.

(5) In 10 days or two weeks repeat the latter.

(6) When fruit begins to color spray with the copper acetate solution.

(7) Repeat the latter in a week or ten days.

This is evidently a larger number of applications than prune growers can afford unless it can be shown that they are all necessary. We believe that except on peaches sprays No. 2 and 5 of the above list may be omitted, and that if care be taken to carefully examine each tree just as the fruit is coloring and to remove all infested fruits sprayings 6 and 7 may also be omitted unless the weather conditions appear favorable for the rapid spread of the disease. Should the weather become moist and warm, however, the applications of copper acetate should be made immediately.

Bordeaux mixture can be used for all applications but it is liable to discolor the fruit if used for the late applications. For the last sprayings, therefore it is better to use the copper acetate solution, using 4 oz. copper acetate to 45 gallons of water. Bordeaux mixture is ordinarily made as follows:

Copper sulphate	6 pounds.
Lime (unslaked)	4–6 pounds.
Water	50 gallons.

So much depends upon the correct preparation of bordeaux mixture that we quote in full the directions for its preparation which are given by Dr. Galloway of the United States Department of Agriculture:

"It has been found that the method of combining the ingredients has an important bearing on both the chemical composition and physical structure of the mixture. For example, if the copper sulphate is dissolved in a small quantity of water and the lime milk diluted to a limited extent only, there results, when these materials are brought together, a thick mixture, having strikingly different characters from one made by pouring together weak solutions of lime and copper sulphate. It is true, furthermore, that if the copper sulphate solution and lime milk are poured together while the latter or both are warm, different effects are obtained than if both solutions are cool at the moment of mixing.

"Briefly, the best results have been obtained from the use of the bordeaux mixture made in accordance with the following directions: In a barrel or other suitable vessel place 25 gallons of water. Weigh out 6 pounds of copper sulphate, then tie the same in a piece of coarse gunny sack and suspend it just beneath the surface of the water. By tying the bag to a stick laid across the top of the barrel no further attention will be required. In another vessel slack 4 pounds of lime, using care in order to obtain a smooth paste, free

from grit and small lumps. To accomplish this it is best to place the lime in an ordinary water pail and add only a small quantity of water at first, say a quart or a quart and a half. When the lime begins to crack and crumble and the water to disappear add another quart or more, exercising care that the lime at no time gets too dry. Toward the last considerable water will be required, but if added carefully and slowly a perfectly smooth paste will be obtained, provided, of course, the lime is of good quality. When the lime is slacked add sufficient water to the paste to bring the whole up to 25 gallons. When the copper sulphate is entirely dissolved and the lime is cool, pour the lime milk and copper sulphate solution slowly together into a barrel holding 50 gallons. The milk of lime should be thoroughly stirred before pouring. The method described insures good mixing, but to complete this work the barrel of liquid should receive final stirring, for at least three minutes, with a broad wooden paddle.

"It is now necessary to determine whether the mixture is perfect —that is, if it will be safe to apply it to tender foliage. To accomplish this, two simple tests may be used. First insert the blade of a penknife in the mixture, allowing it to remain there for at least one minute. If metallic copper forms on the blade, or, in other words, if the polished surface of the steel assumes the color of copper plate, the mixture is unsafe and more lime must be added. If, on the other hand, the blade of the knife remains unchanged, it is safe to conclude that the mixture is as perfect as it can be made. As an additional test, however, some of the mixture may be poured into an old plate or saucer, and while held between the eyes and the light the breath should be gently blown upon the liquid for at least half a minute. If the mixture is properly made, a thin pellicle, looking like oil on water, will begin to form on the surface of the liquid. If no pellicle forms, more milk of lime should be added.

"The foregoing directions apply to cases where small quantities of the mixture are needed for more or less immediate use. If spraying is to be done upon a large scale, it will be found much more convenient and economical in every way to prepare what are known as stock solutions of both the copper and lime. To prepare a stock solution of copper sulphate, procure a barrel holding 50 gallons. Weigh out 100 pounds of copper sulphate, and after tying it in a sack suspend it so that it will hang as near the top of the barrel as possible. Fill the barrel with water, and in two or three days the copper will be dissolved.

"Now remove the sack and add enough water to bring the solution again up to the 50 gallon mark, previously made on the barrel. It will be understood, of course, that this second adding of water is merely to replace the space previously occupied by the sack and the crystals of copper sulphate. Each gallon of the solution thus made will contain 2 pounds of copper sulphate, and, under all ordinary conditions of temperature, there will be no material recrystallization, so that the stock preparation may be kept indefinitely.

"Stock lime may be prepared in much the same way as the copper sulphate solution. Procure a barrel holding 50 gallons, making a mark to indicate the 50 gallon point. Weigh out 100 pounds of fresh lime, place it in the barrel and slack it. When slacked add sufficient water to bring the whole mass up to 50 gallons. Each gallon of this preparation contains, after thorough stirring, 2 pounds of lime.

"When it is desired to make bordeaux of the 50 gallon formula it is only necessary to measure out 3 gallons of the stock copper solution, and, after thorough stirring, 2 gallons of the stock lime; dilute each to 25 gallons, mix, stir, and test as already described. One test will be sufficient in this case. In other words, it will not be necessary to test each lot of bordeaux mixture made from the stock preparation, provided the first lot is perfect, and no change is made in the quantities of the material used. Special care should be taken to see that the lime milk is stirred thoroughly each time before applying. As a final precaution it will be well to keep both the stock copper sulphate and the stock lime tightly covered."

Acknowledgements are due Dr. W. J. Beal of the Michigan Agricultural College, under whose directions all of our laboratory studies of *Monilia* were conducted.

THOS. M. GATCH, A. M., Ph. D.,
President of the College.

LIST OF BULLETINS

(In print) published by the Oregon Agricultural Experiment Station to November, 1898.

No. 6, 1890—Chemistry, Zoölogy ..... Washburn
No. 7, 1890—Small Fruits and Vegetables ..... Coote
No. 8, 1891—Varieties of Wheat and Flax ..... French
No. 10, 1891—Entomology ..... Washburn
No. 27, 1893—Plant Diseases, etc. ..... Craig
No. 28, 1894—Pig Feeding, continued ..... French
No. 29, 1894—Horticulture, Pruning, etc. ..... Coote
No. 30, 1894—Potatoes and Roots, continued ..... French
No. 31, 1894—Codlin Moth, Hop Louse ..... Washburn
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No. 33, 1894—Tent Caterpillar ..... Washburn
No. 34, 1895—Fruits and Vegetables ..... Coote
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No. 36, 1895—Composition and Use of Fertilizers ..... Shaw
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