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DISEASES OF ILLINOIS FRUITS

By H. W. ANDERSON

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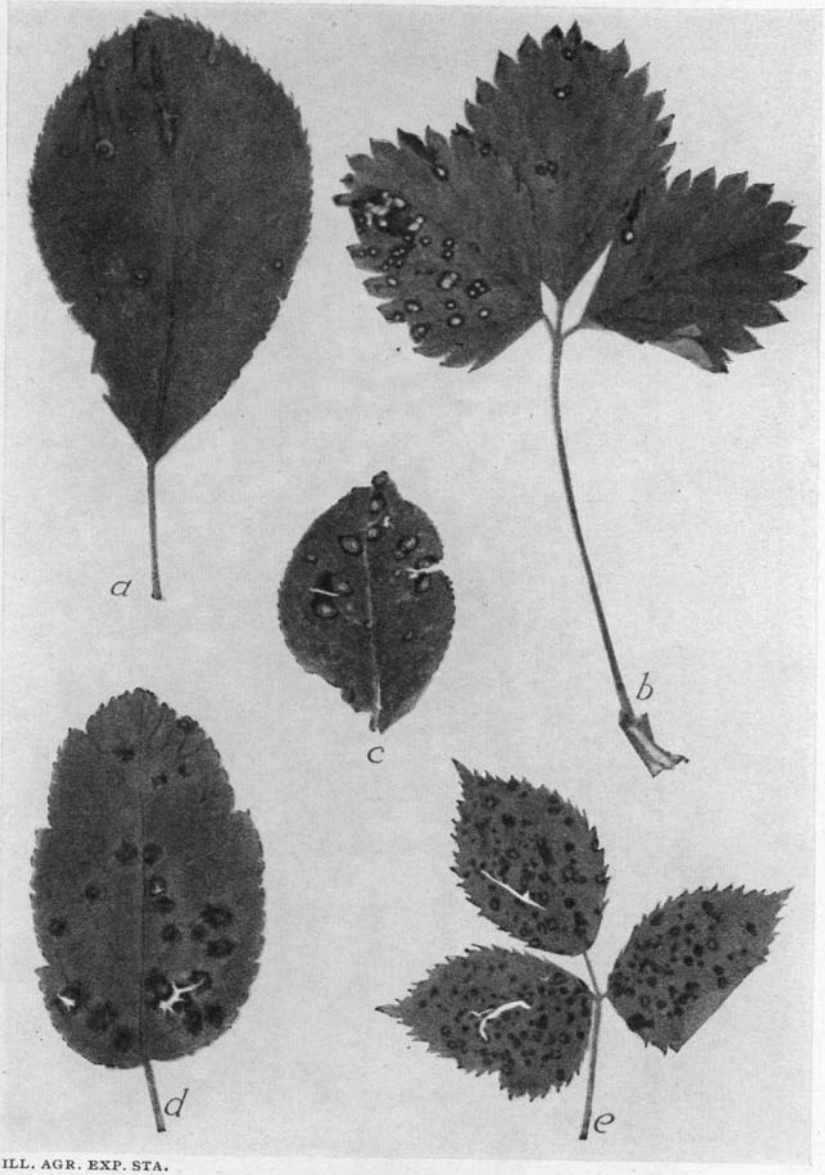

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PLATE I.—TYPES OF LEAF SPOTS

(a) Black Rot, or Frog Eye of Apple; (b) Leaf Spot of Strawberry; (c) Leaf Spot of Pear (Septoria); (d) Apple Scab; (e) Leaf Spot of Blackberry

DISEASES OF ILLINOIS FRUITS

By H. W. ANDERSON, Assistant Chief in Pomology

INTRODUCTION

Fruit diseases are causing each year an enormous financial loss thru destruction of the fruit crop and thru reduction in the quality of the fruit. All commercial fruit growers are awake to the seriousness of the disease situation and await with interest the slow development of control measures. The more progressive growers are constantly experimenting to improve on existing methods of control or to devise new ones. Such men are usually very keen observers and their long association with fruits has trained them to find instinctively the most effective methods of disease control. It is unfortunately true, however, that each year the number of diseases is increasing, and that new maladies are constantly appearing or spreading from one section of the country to another. These newly introduced diseases usually develop unrecognized for a number of years and become firmly established in their new area before the orchardist is fully aware of their presence. Then follows a hard fight to keep them in check or to reduce the loss to a minimum.

It is one of the purposes of this circular to acquaint the grower with the characteristics of new diseases, so that he may recognize them as soon as they appear. The main object, however, is to present to the Illinois grower a list of the diseases which occur on fruits in this state, and to suggest methods for their control. Each disease is described and illustrated in such a manner that it is hoped the grower will be able to recognize it when he encounters it. Whenever possible, the complete life history of the organism causing the disease is given, in order that the orchardist may have a basis for logical experimentation. For example, if it is known that a certain fungus lives over winter on dead branches and reinfects the tree the following year from such branches, it is evident that the removal and burning of these branches will aid in checking the disease. Or if the grower knows that infection of apple scab takes place during a rainy period at a certain season of the year, he can make a special effort to apply his spray in time to have the leaves covered when the rain comes and thus prevent the infection.

Before taking up the specific fruit diseases, an account of plant diseases in general is given, together with the life history of a typical fungus and a bacterium. It is hoped that such an introduction will aid in a clearer understanding of the technical discussion necessary for accurate descriptions in the body of the circular.

CAUSES OF PLANT DISEASE

A plant is diseased when it fails to develop or function in a normal manner. Such a broad definition includes abnormal conditions brought about by adverse climatic conditions or mechanical injury; hence injuries from spraying, from sun scald, or from frost would be called diseases. In this circular, however, only those diseases caused by plant parasites (the fungi and bacteria), and a few so-called "physiological" diseases, such as raspberry leaf curl, will be discussed.

THE FUNGI

Fungi cause most of the serious diseases of fruit crops. They constitute a group of plants which do not have the green coloring matter possessed by most of the common flowering plants. A great many of them live on decaying vegetable matter, from which they obtain their food. Such fungi are called *saprophytes*. The fungi causing plant disease, however, derive their food for the most part from the living plant and are called *parasites*.

The Fungus Plant.—Instead of having stem, root, and leaves, the fungus plant is made up of a large number of very small thread-like structures which grow in and on the *host plant* (the plant upon which the fungus lives). These threads are called *hyphae* and together they make up a mold-like mass of material called the *mycelium* (Fig. 1, E). The individual threads, or hyphae, in the case of the parasitic fungi, grow in the tissues of the plant and extract nourishment from them. This frequently causes the death of the part of the host plant attacked and results in a "leaf spot," if on a leaf, or a rotted area if on the fruit. The fungus may continue to grow in the tissues of the host, but usually after a certain time it begins to form its fruit, just as the peach or apple tree ceases its vegetative growth as the season advances and gives most of its energy and food to developing the fruit.

The fruiting part of the fungus is usually formed in the dead or deformed area produced by its growth. These fruiting bodies are always minute and vary widely in their structure in the different kinds of fungi. In order to give a more definite idea of them, the following description is given of the life history of a fungus.

LIFE HISTORY OF A TYPICAL FUNGUS (APPLE SCAB)

The mycelium of the apple scab fungus grows just underneath the outermost layer of the apple leaves and fruit, deriving its nourishment from the epidermis, or skin. After growing for some time and forming a spot about a quarter of an inch in extent (Plate I), the fungus forms a rather dense mat of hyphae over this area and then produces

one form of its fruit. From this matted mycelium short stalks are sent up into the air, pushing up and usually rupturing the cuticle, or outermost layer of the leaf or fruit (Fig. 1, B). On these stalks

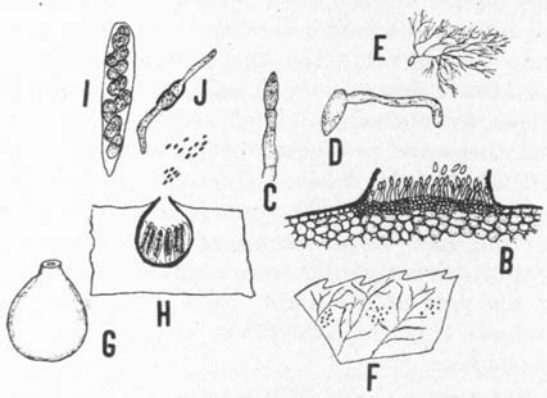

FIG. 1.—LIFE HISTORY OF THE APPLE-SCAB FUNGUS

B, Section of lesion of imperfect stage; C, Conidiophore and conidium (summer spore) of scab; D, Germinating conidium; E, Mycelial growth developing from conidium; F, Perfect stage on leaf. Black dots represent the perithecia; G, Single perithecium; H, Cross-section of leaf with embedded perithecium showing asci and ascospores. Ascospores are being discharged into the air from the perithecium; I, Single ascus with eight ascospores; J, Germinating ascospore

(*conidiophores*) are borne the "seeds" of the fungus, very small, oval bodies which cannot be seen with the naked eye. On account of their small size and simple structure they are not called seeds but *spores* (Fig. 1, C). These spores, however, correspond in a way to the seeds of higher plants in that they are able to live for some time without nourishment and reproduce the fungus plant when placed on the leaf or fruit of the apple. Just as the seed germinates when placed in the moist, warm earth, so do these spores germinate when placed on the leaf and given the proper amount of moisture and warmth.

When the spore germinates, a thread-like structure, called a germ tube (Fig. 1, D), but really the beginning of the new fungus plant (Fig. 1, E), grows from the spore and enters the host tissue. Since several thousand spores can be produced on a spot a quarter of an inch in diameter, and each of these can cause a new scab spot, it is hardly to be wondered at that so many apples are scabby before the end of the season. Entrance of the germ tube into the plant is spoken of as *infection.* It may be several days or even two weeks after infection that the scab spots become evident on leaves and fruits.

The spores produced in these cushions on the scab spots are often called summer spores. They are also called *conidia* and in the fol-

lowing descriptions this term will be applied to all spores of this nature, since it distinguishes them from the more resistant resting spores described below.

Since these spores (conidia) are not able to live over winter, how does the fungus pass from one season to another? On the fallen leaves there are formed other fruiting bodies which are flask-like in structure and buried deep in the dead tissues of the leaf (Fig. 1, F, G, H). These structures are called *perithecia* (singular, *perithecium*), and in them are produced little sacs called *asci* (singular, *ascus*) (Fig. 1, H, I). In these sacs are formed eight spores which are called *ascospores* (Fig. 1, I) to distinguish them from the summer spores, or conidia. These spores are produced in the spring, so that after all they are not winter spores. The mycelium in the fallen leaf is really the part of the plant which lives over, but since this mycelium produces only the ascospores, these are usually spoken of as the winter spores.

How do these spores in the fallen decaying leaves under the tree get into the leaves and fruit on the tree? In the first place there is a device by which the ascospores are shot upward into the air when the proper conditions arise in the spring (Fig. 1, H). They are then carried to the lower leaves by the wind, since they are very small and float about like dust particles. Here the ascospore produces a germ tube, similar to that formed by the conidium (Fig. 1, J), which enters the leaf and, by its branching and further growth, forms the mycelial cushion on which the conidia are produced. It is, of course, necessary for only a few spots to be produced from the ascospores, since each spot can give rise to thousands of conidia, which, in turn can be carried by wind and rain to all parts of the tree and orchard, causing a general infection of the entire orchard.[1]

In many parasitic fungi the winter stage is not present, or is at least unknown and unimportant so far as the life history of the fungus is concerned. In these cases either the conidia are able to live over winter or the mycelium hibernates in the host tissue and in the spring continues its development in the ordinary manner.

Some fungi are only weakly parasitic and live most of their life on dead wood or decaying vegetable matter. Under certain favorable conditions they are able to attack living parts of the plant and thus become true parasites.

A group of fungi called the *rusts* are peculiar in that they may live part of their life on one kind of plant and the remainder upon an entirely different species. For example, the apple-rust fungus causes a serious disease of the apple during a part of its life and then

[1]It is possible for the scab fungus to live over winter in the tissues of twigs and produce new masses of conidia in the spring. This rarely takes place but it illustrates another method of carrying the fungus plant thru the winter.

is transferred to the cedar tree, where it produces the large brown galls commonly called cedar apples.

Thus, the fungi in general are like other plants in that they have a vegetative growth followed by a fruiting or reproductive phase in their life history. In the vegetative period the fungus plant spreads thruout a certain area in the leaf, fruit, or branches of the host, deriving nourishment from tissues of the host plant and usually causing their death. The vegetative phase is followed by the reproductive period, during which the fungus develops numerous spores of one type or another. These are very small and light and are widely spread by wind, insects, water, and other agents. Falling on new parts of the host plant, these spores germinate when the weather is favorable and, infecting the host, start anew the vegetative phase.

BACTERIA

Life History.—Some plant diseases, such as fire blight of pear and crown gall of many plants, are caused by a group of very minute organisms called bacteria (singular, bacterium) (Fig. 2). The life history of these microscopic plants is slightly different from that of fungi. Bacteria which cause plant diseases are minute rod-like organisms, from $\frac{1}{10,000}$ to $\frac{1}{25,000}$ of an inch in length and less than half that in diameter. They reproduce by dividing in the middle, each half becoming a new plant (Fig. 2). This division may take place very rapidly, so that in a few days millions of bacteria may be produced from a single organism. Thus, the progeny of one bacterium at the rate of one division an hour would be 16,777,216 new bacteria at the end of twenty-four hours. It is not unusual for the bacteria to divide every twenty minutes under favorable conditions.

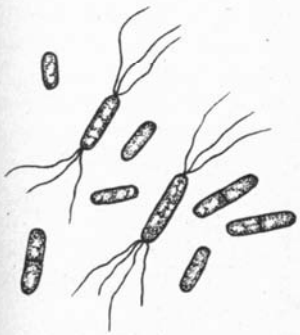

Fig. 2.—Bacteria of fire blight, showing organs by which they propel themselves. Note bacteria dividing to form two individuals

Means of Dissemination.—Most disease-producing bacteria are motile, i.e., they are able to swim about by means of minute hair-like structures called *flagella* (Fig. 2). The bacteria themselves are carried by insects, wind, and rain from one plant to another; hence it is not necessary for them to produce spores as do the fungi. Some kinds of bacteria do form internal spores which are very serviceable for carrying them over unfavorable seasons, but as none of these cause diseases of plants, they will not be considered.

When the bacteria are carried to a plant by some agent they must gain an entrance into the tissues of the host, since they do not produce a mycelium as do the fungi. If they did not get inside

the host tissue the sunlight and drying effect of the atmosphere would soon kill them. Frequently, insects which carry them from diseased to healthy plants aid in introducing them into the tissues. These insects usually feed upon the plant either by chewing or inserting their beaks to suck the juices, and thus they bring the bacteria in direct contact with internal tissues. In other cases, as in blossom blight of pear and apple, the bacteria are carried from one flower to another by insects gathering nectar. When either rain or wind is the carrier, the bacteria are able to gain entrance thru wounds, or enter directly into healthy tissue thru minute breathing pores which are found scattered over the surfaces of leaves and twigs. After entering, the bacteria absorb their food from the host tissues, then divide as described, and in a short time produce thousands upon thousands of new individuals.

INFECTION AND ITS RELATION TO THE APPEARANCE OF THE DISEASE

When a diseased spot appears on a leaf or fruit, it is evident that the plant is suffering from the attack of some parasite. But it is also evident, from what has been said before, that the parasite has been at work for some time, and that infection might have taken place a week or so previous to the appearance of the spot. The fungus, if it be a fungus, has been developing during this period, has already "dug itself in," and is producing millions of spores which may in turn infect the sound parts of the plant or other healthy plants.

Importance of Preventive Control.—It is impossible, except in rare instances, to destroy a fungus or bacterium once it has entered the plant tissues. This is an important fact to remember in applying control measures, since it is evidently necessary to prevent entrance of the parasites into the tissue in the first place. This can be done only by applying a fungicide to the surface of the leaf or fruit. The wise farmer takes every precaution against the introduction of weeds into his wheat or clover seed, but if introduced in spite of his care, he sees that the seed from these weeds is not allowed to reinfect his soil, or be carried over into his wheat seed. In a like manner the wide-awake orchardist, detecting the presence of a disease in his trees, doubles his efforts to keep the fungus from gaining new footholds. This fundamental principle cannot be over emphasized, for the whole practice of disease control by spraying is based upon it.

SYMPTOMS OF FRUIT DISEASES

The grower who is unfamiliar with a particular disease is frequently at a loss to know what to look for in his orchard. It is good general practice to be on the lookout for any diseased condition, and

having found such a condition to set about determining the specific cause. This can be done best by reading carefully the account of each disease given for the particular plant in question, arriving at the true cause by comparison and elimination. Under each disease description, an account is given of the *symptoms*. Too much reliance cannot be put upon these alone, since many diseases have identical gross symptoms. For example, in the apple, any root rot, mouse injury, or the attack of borers may produce a gradual yellowing of leaves and sickly appearance of the tree.

The general symptoms indicating a diseased condition are:

1. *Spots on Leaves or Stems.*—Spots with more or less regular outlines appear on the surfaces of the leaves. Such diseases are called leaf spots. If the central dead area drops out, a shot-hole effect is produced. Examples: leaf spot of cherry (Fig. 45) and bacterial shot-hole of peach (Fig. 38). Similar spots may appear on the stem, as in raspberry anthracnose (Fig. 46).

2. *Wilt or Blight.*—The ends of branches, or the entire plant, wilt or die rather suddenly without the leaves falling. Examples: twig blight of pear and apple (Figs. 16 and 30).

3. *Yellow, Sickly Foliage.*—This may or may not be followed by defoliation or death of the plant or branches involved. A condition of this nature usually indicates some trouble with the root system or crown of the tree.

4. *Defoliation, or Dropping of Leaves.*—Example: cherry leaf spot (Fig. 45).

5. *Rusts.*—Yellow or orange-colored spots on leaves, fruit, and twigs, without death of the host tissues, are often caused by rust fungi. Examples: orange rust of blackberries (Fig. 52) and apple rust (Fig. 12).

6. *Mildew.*—A white or grayish growth on the surface of the leaves of young shoots is produced by the mycelia of certain superficial fungi, *the powdery mildews*. There is also a class of *downy mildews* which produce a more dense, grayish growth usually confined to a small area (Fig. 59).

7. *Spots, Blotches, or Scab Areas on the Fruit.*—(See Plate II, d, e.)

8. *Rots on the Fruit.*—Usually starting as a minute water-soaked area (Plate II), the rot spreads and frequently involves the entire fruit. Rots may be soft or firm, dry or wet, dark or pale, or may vary between these extremes.

9. *Cankers.*—These "sores" on the trunk or limbs usually result in dead areas (Figs. 4 and 8). In some cases cankers are in the outer portion of the bark only.

10. *Galls, Tumors, or Abnormal Enlargements.*—(Figs. 22 and 43.) Galls on leaves, branches, and stems may be produced by the sting of certain insects. Crown gall of numerous plants, however, is caused by a bacterium.

CONTROL OF FRUIT DISEASES[1]

Control measures depend to a large extent upon a thoro knowledge of the cause of the particular diseased condition. It is evidently useless, for example, to spray the foliage of a raspberry bush suffering from crown gall or yellows. Cases are not wanting where orchardists have attempted to prevent the dying of sickly looking trees by numerous applications of spray mixtures, when an examination of the base of the tree revealed the fact that the trunk was almost girdled by the gnawing of mice.

Methods for the control of fruit diseases may be classified as follows:

1. Spraying
2. Cutting out and destroying diseased parts
3. Rotation of crops
4. Avoiding regions where the disease prevails to a destructive extent
5. Selecting or breeding disease-resistant varieties
6. Destroying the host plants which harbor one stage of the parasite
7. General sanitation (pruning, cultivation, care of wounded surfaces, etc.)

1. *Spraying.*—In general, spraying is practiced against fungi which gain entrance to the host thru infection by means of a germ tube. It is usually ineffective against bacterial diseases, those caused by adverse environmental conditions, and other so-called physiological diseases. It is also ineffective, as a rule, in the case of canker diseases, where the fungus lives from year to year in the bark or wood. It may aid in the control of these maladies, in that the original infection may be prevented.

Spray mixtures are chemical poisons which are applied to the external surface of the plant in such a manner as to kill the germ tube of the fungus, or prevent the germination of the spore, or, rarely, to kill the superficial mycelium of the fungus. On this account the surface must be thoroly coated. The spray must be such that it stays on the surface during a fairly long period and must not be easily washed off. It is also essential that it be non-poisonous to the plant to which it is applied. These conditions are met only when the chemicals which poison the fungus are not readily dissolved, yet go into solution in sufficient quantity to prevent the development of the fungus. Frequently the problem is further complicated by the fact that a spray mixture which will not injure one kind of fruit will

[1]A spray schedule for the tree fruits discussed in this circular is given on page 113. The preparation of spray mixtures is described on pages 12 to 15.

seriously damage another. Thus, apple trees may be sprayed with solutions which would seriously injure peach trees.

2. *Cutting Out and Destroying Diseased Parts.*—Frequently the disease-producing organism is carried over winter on some part of the host, as for example, in cankers on the limbs. Again, diseased fruit or leaves dropping to the ground may harbor the fungus over winter and furnish a means of reinfection in the spring. Such "starters" should be destroyed in so far as is practical. The labor involved in some cases is so great as to make this method impracticable.

3. *Rotation of Crops.*—This method of control is based on the fact that many fungi live in the soil or on decayed parts of the plant which cannot be conveniently removed. If the crop upon which the disease occurs is followed for a year or so by crops not subject to it, the fungus frequently dies out to a large extent. This method is not so applicable to a fruit crop as to vegetable and field crops, since the former is scarcely ever a yearly crop. Crown gall of raspberries and certain root rots can frequently be controlled in this manner.

4. *Avoiding Regions Where the Disease Prevails to a Destructive Extent.*—Orchards planted on land recently cleared frequently suffer severely from Armillaria root rot. Such locations should be avoided.

5. *Selecting or Breeding Disease-Resistant Varieties.*—It is a matter of common knowledge among fruit growers that some varieties are much more prone to "take" a disease than others. Almost all parasites show this selective action; for example, Jonathan apples blight much more severely than Grimes or Ben Davis. One soon comes to the opinion that this or that variety has in it an inherent quality which makes it more or less subject to a certain disease. While this is in the main true, there are frequently striking exceptions to any general statement regarding the relative resistance of a variety.

It should not be forgotten, however, that there does exist a varietal resistance among most fruits, and the selection of varieties for commercial orcharding should be governed by this fact as well as by the relative market value of the varieties. It would, for example, be unwise to plant Smith Cider apples in a region where blotch is prevalent, or Cumberland raspberries where anthracnose is known to cause serious damage, if other equally good resistant varieties could be used.

There are few varieties which are absolutely immune to a disease. Relatively speaking, however, those varieties which are highly resistant are said to be "free" from the disease, and from a commercial standpoint they are classed as immune varieties.

Under most of the diseases described in the following pages the varietal susceptibility is given for *conditions as they prevail in Illinois.* The lists given are based on information received from a large number of growers, together with observations extending over a

number of years by members of the horticultural staff of the Illinois Experiment Station.

6. *Destroying the Host Plants which Harbor One Stage of the Parasite.*—Destruction of the red cedar to prevent the development of apple rust is an example of this method of disease control.

DIRECTIONS FOR MAKING THE STANDARD SPRAYS[1]

BORDEAUX

Formula.—Bordeaux may be made according to the following formula:

3 pounds of copper sulfate
4 pounds of lime
50 gallons of water

Equipment.—When the small home orchard composed of only a few trees is to be sprayed, the equipment should consist of a 50-gallon barrel, two tubs of at least 25-gallons capacity, two buckets, and a paddle.

Directions for Mixing.—Arrange the tubs so that one is on either side of the barrel. Place in one of the tubs 25 gallons of water and dissolve in it 3 pounds of copper sulfate suspended in a coarse sack just below the surface of the water. About one hour should be allowed for this; but if hot water is available, the copper sulfate can be dissolved in a small quantity in much less time, and the solution then diluted to 25 gallons with cold water.

In the other tub carefully slake 4 pounds of stone lime, using only sufficient (hot) water to have the lime, when thoroly slaked, in the form of a thick paste, in which form it should be allowed to cool. When cold, dilute to 25 gallons.

The copper sulfate and milk of lime are now ready to mix; two persons are necessary for the operation. Have the contents of each tub well stirred; then pour a bucketful of each mixture simultaneously into the barrel, allowing the two streams to come together. Continue in the same way until the entire amount is made. Thoroly agitate the blue mixture in the barrel, and transfer it *thru a strainer* into the spray tank. It is now ready for application.

COMMERCIAL LIME SULFUR

Where a small acreage is to be sprayed, it is more convenient and sometimes cheaper to purchase lime sulfur than to attempt to make it. This material can be purchased from several reliable manufacturers. It is cheaper when purchased in 50-gallon lots than by the gallon.

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[1]From Ill. Agr. Exp. Sta. Circ. 212. Directions for time of applying and further notes on preparation are given in the spray schedule for tree fruits, page 113.

HOMEMADE LIME SULFUR

Formulas.—The following formulas are in common use in Illinois:

A	B
100 pounds of sulfur	100 pounds of sulfur
50 pounds of lime	50 pounds of lime
50 gallons of water	66 gallons of water

Formula A is more generally used than Formula B, as it is more concentrated, more convenient to remember, more convenient for calculations, and is based on a barrel unit. It is highly recommended after a thoro trial in Illinois. Formula B, however, is more economical of sulfur, about 6 percent more sulfur going into solution than when Formula A is used.[1]

Lime sulfur is prepared by cooking the ingredients together at boiling temperature for 35 to 50 minutes, or until all the free sulfur has dissolved. Cooking may be done with live steam, in steam-jacketed kettles, or in caldrons over a fire.

Equipment for Formula A.—Provide two large tubs by cutting a large palm-oil cask across the middle. Before cutting, draw two stout wires around the middle of the cask about two inches apart, cutting between them. Staple the wires in place to act as top hoops for the tubs. Bend a piece of one-inch gas pipe into nearly circular form, so that it will lie on the bottom of the tub. Cap the free end, punch holes at intervals of four inches to permit the escape of live steam, and attach the other end to a steam feed pipe leading into a steam boiler. A steam threshing-machine engine can usually be hired for the cooking in case the orchardist does not have a steam boiler. Various systems of elevated platforms may facilitate the work, but these depend on the arrangements in the individual cooking plants.

A mechanical agitator must be provided which will keep the solution stirred constantly from the beginning to the end of the cooking. A good form of agitator is made to work with sweeping arms, rotating on a shaft placed in the center of the tub and operated by bevel gears connected with the shaft either above or below the tub. If below the tub, a stuffing box is necessary to prevent the solution from leaking where the shaft enters the tub. The agitator works on the bottom of the tub underneath the screen, which is described later.

A large-sized spigot, thru which to run the solution from the tubs after cooking, should be provided on one side near the bottom.

Three inches from the bottom of the tub, supported by wooden blocks at the outer edge and by the agitator bearing in the center, place a half-inch screen of No. 9 wire cut with a cold chisel to fit the tub snugly at the point where the screen rests.

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[1]Van Slyke, L. L., New York (Geneva) Agr. Exp. Sta. Bul. 329, 1910. Trans. Ill. State Hort. Soc. 1910, N. S., Vol. 44, pp. 164-165.

Directions for Mixing Formula A.—Depending on the size of the tub, quantities from 50 to 200 gallons may be made at one time. To make 50 gallons, place 50 pounds of fresh, unslaked stone lime on the screen near the bottom of the tub, and pour in sufficient water, preferably hot, to start the lime slaking rapidly. With the lime slaking freely, pour in 100 pounds of sulfur, and add water, preferably hot, to make up a quantity of about 40 gallons. Turn on the steam and cook until the free sulfur has disappeared. The solution must measure 50 gallons at the conclusion of the process. Should it measure less, water should be added to make up this volume. The clear lime-sulfur solution may be stored in large casks, barrels, or a cistern until needed for use.

Directions for Mixing Formula B.—When lime sulfur is cooked over a fire, the following directions will be found practical: Place in a large kettle 15 gallons of water and 50 pounds of good lime, free from air-slaked particles. When the lime is slaking vigorously, pour in 100 pounds of powdered sulfur and mix thoroly with the lime. Gradually add sufficient water to prevent the lime from drying out during the process of slaking. As soon as the lime is thoroly slaked and the sulfur thoroly mixed, add enough water to bring the total volume to 66 gallons or a little more. Continue boiling for 30 to 45 minutes, adding enough water from time to time to keep the volume at 66 gallons. A 75-gallon feed-cooker has proved to be a great improvement for this work.

ARSENATE OF LEAD

Arsenate of lead comes in both paste and powdered form. Paste arsenate of lead contains about 50 percent water. Powdered arsenate of lead is water-free. This difference explains why twice as much paste arsenate of lead as powdered should be used in each 50 gallons of spray. Always make arsenate of lead into a thin paste before straining into spray barrels.

BORDEAUX ARSENATE OF LEAD

Generally it is found advantageous to combat insects with the same application that is used against fungous diseases. This can be very satisfactorily accomplished by mixing the required amount of arsenate of lead with the diluted lime just before the lime is mixed with the copper-sulfate solution.

LIME SULFUR ARSENATE OF LEAD

When using lime sulfur and arsenate of lead in combination, first place the lime sulfur in a barrel and fill to about two-thirds capacity with water. Then, with the agitator on the pump working, strain the arsenate of lead into the barrel, adding enough water to complete the volume desired.

SELF-BOILED LIME AND SULFUR

Self-boiled lime and sulfur is a special spray for peaches and should not be confused with the cooked solutions just described. This spray is a mechanical mixture; the only heat employed in its preparation is that furnished by the slaking lime. This heat of slaking lime has the faculty of breaking the particles of sulfur into finer divisions than can be accomplished by means of a grinding machine.

Formula.—The mixture which has proved most satisfactory is one made according to the following formula:

8 pounds of lime
8 pounds of sulfur
50 gallons of water

Extreme care must be exercised in the preparation of this mixture and the following directions carefully adhered to. A slow-slaking lime free from all air-slaked particles should be used. Ground commercial sulfur which contains no hard lumps is satisfactory.

Equipment.—The equipment needed for making self-boiled lime and sulfur consists of a smooth-bottomed barrel or tub, a hoe, paddle, buckets, and scales.

Preparation.—If 50 gallons of the mixture are to be made, place 8 pounds of lime in the barrel or tub with 1 or 2 gallons of water. As soon as the lime is slaking vigorously, put into it 8 pounds of sulfur. The mixture should be constantly stirred, and more water added as needed to form at first a thick paste of the mixture, and finally a thin paste.

When the boiling has stopped, and before any red or orange streaks appear, add several gallons of cold water to cool the mixture. Strain into the spray tank, using the paddle to work thru everything that will pass thru the strainer; then dilute to 50 gallons. The mixture is now ready for application. The agitator should be allowed to run a few minutes before starting to spray, and should be kept going as long as any spraying is being done, as the mixture settles very rapidly.

SELF-BOILED LIME AND SULFUR WITH ARSENATE OF LEAD

It is often desirable to apply arsenate of lead with self-boiled lime and sulfur, and this may be satisfactorily done. After the mixture is all in the spray tank and diluted to nearly 50 gallons, start the agitator and strain into the self-boiled lime and sulfur the required amount of arsenate of lead.

NICOTINE SULFATE

This material may be purchased in concentrated form. One gallon will make 1,000 gallons of spray mixture. The cost is very high and consequently this material should be used only when the orchardist is sure that aphids are actually causing damage.

PART I

DISEASES OF POMACEOUS FRUITS

The apple, pear, and quince are subject to a number of diseases in common. Fire blight, black rot, bitter rot, brown rot, and crown gall are found on all three varieties of fruits, while the Fabraea leaf spot is common to the quince and the pear. There are usually marked differences, however, in the relative severity with which these diseases attack the three groups. For this reason diseases common to all will be fully described under the host upon which they are most frequently found or to which they do the most damage from a commercial standpoint, and only supplementary accounts will be given under the remaining hosts.

Pomaceous fruits are also subject to a number of diseases common to a large group of other plants. These are treated under the host to which they are usually most injurious. Pome fruits are tree fruits and are subject to those wood and root rots common to many trees.

Since the fruit is usually placed in storage, the storage rots assume unusual importance.

APPLE DISEASES

SCAB

In all countries where the apple is grown, scab is one of the most common diseases. In some regions it is called "the fungus" because it is the one disease universally known to the orchardist as being caused by a fungous parasite. In Australia, New Zealand, and South Africa it is called "black spot."

Financial Loss from Scab.—While scab does not cause entire loss of the fruit, as does bitter rot, it ranks first among all apple diseases from a financial standpoint. Scabby fruit does not keep well in storage, and the disfiguring and deforming effect caused by its attack reduces the sale value. The loss in the United States from scab is estimated to be nearly $50,000,000 a year, based on the apple yield in 1909. A low estimate of ten dollars an acre would make the yearly loss in Illinois $1,500,000.

Early History.—Apple scab was described in Europe as early as 1819 and evidently was well known long before that date. It was probably brought to America with the first European apples introduced into this country, since specimens of the disease were collected in Pennsylvania and New York as early as 1834. The first reference to scab in this state is found in the report of the Illinois Horticultural Society for 1863, and at that time it seemed to be a disease well known to orchardists.

It was formerly believed that the scab of apple and pear were identical, and that pear scab could be transferred to the apple and vice versa. This has proved to be a false assumption, and the two diseases are now regarded as distinct. The disease is not known to occur on hosts other than the apple and a few other species of the Malus group. Closely related diseases occur on some native hawthorns and on pear.

Susceptibility of Different Varieties.—All varieties of apple are subject to this disease, altho some are notoriously susceptible while others are regarded as almost immune. A variety regarded as immune in ordinary seasons may, under more favorable conditions for the development of the fungus, show as much scab as a very susceptible variety. It is true also that there are unaccountable variations in different parts of the country. Under Illinois conditions the majority of growers list as *very susceptible* varieties, Ben Davis, Gano, Rome Beauty, Snow (Fameuse), Willow Twig, Oliver (Senator), Kinnaird, Red June, Lady, McIntosh, Delicious, and Early Harvest; as *moderately susceptible,* Stayman Winesap, Benoni, Northern Spy, Salome, Northwestern Greening, Romanite, Aiken, Huntsman, Stark, Maiden Blush, and Winesap; as *relatively immune,* Jonathan, King David, Grimes, Duchess (susceptible in northern part of the state), Transparent, York Imperial, Ingram, Wolf River, Minkler, Wealthy, Chenango, and Ralls.

Nature of Loss from Scab.—Scab affects the fruit, leaves, and twigs, but is rarely found on the twigs except in the case of a few very susceptible varieties. There is often a serious infection of the pedicel and calyx cup of the blossom, resulting in a dropping and consequent reduction in the set of fruit. Hesler and Whetzel summarize the nature of the loss as follows: "(1) Reduction in or destruction of the set of fruit. (2) Impairing the efficiency of the foliage. Affected leaves are often smaller than normal ones and they may fall prematurely. (3) Reduction in size of the fruit. (4) Reduction in quality of the fruit. This is usually regarded as the chief consideration, but obviously other types of losses are nearly of equal importance. (5) The keeping qualities of the fruit are diminished. Pink-rot and other storage troubles commonly follow scab on stored apples. (6) The number of windfalls is increased just before picking time."[1]

Symptoms.—On the leaves, the first appearance of the disease in the spring is indicated by a small, faint, olive-brown, web-like area with branched root-like extensions about the edge. Such an area is made more evident to the eye by holding the leaf against a strong light, when the webby area and fimbricate edge stand out clearly.

On the upper surface of the leaf, the spots are more definite in outline and the central area is much darker (Plate 1, d). These spots

[1]Hesler and Whetzel, Manual of Fruit Diseases, page 5.

are almost circular, usually from one-fourth to three-eighths inch in diameter, but may be smaller when a large number of infections occur on a single leaf. Frequently the area of the leaf on which the spot occurs becomes raised, with a corresponding depression on the lower surface. As the spot grows older the central area often dies and turns brown. This is especially true if sprays are applied after the fungus has produced the primary spots. The infected leaves are frequently smaller than the normal ones, and in cases of severe infection defoliation may result.

On the fruit (Fig. 3), the lesions closely resemble those on the upper surface of the leaf. At first the scab has a gray appearance owing to the fact that the cuticle remains as a thin skin over most of the spot. Later the cuticle breaks away from above the central area and exposes an olivaceous, powdery mass beneath. The scabby appearance of the disease at about this stage is evidently responsible for the origin of the name. As the infected area enlarges, the powdery central portion is weathered away and becomes smooth and russeted. In severe cases of infection the spots may become quite large, coalesce, form a russeted area over one side or end of the fruit, and, by checking the normal development, cause a deformed apple (Fig. 3). As

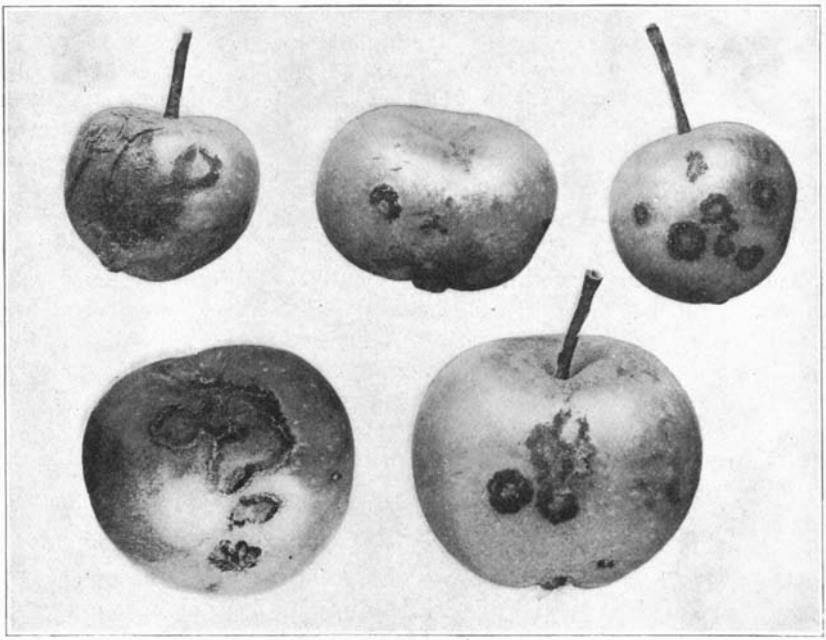

FIG. 3.—APPLE SCAB ON FRUIT
Note cracking and abnormal shape of the apple at the left above

a result the fruit is often cracked. In other cases there seems to be a stimulation of the tissue in the attacked area and this becomes raised in a wartlike manner.

In Illinois the disease is so rarely found on twigs that a detailed description is not necessary.

Cause.[1]—Scab is caused by a fungus, *Venturia inaequalis*. The main facts regarding its life history have been given in the introduction (see page 24 and Fig. 1) and under the symptoms of the disease. Some of the most important points are here summarized.

Ordinarily the fungus passes the winter in infected leaves on the ground. In the spring the ascospores (Fig. 1, H), which are maturing within the perithecia in these old leaves during March and April, are forcibly discharged and, being very light, are carried to the leaves on the lower branches of the trees. Here they germinate, provided sufficient moisture is present (Fig. 1, J). Since ascospore discharge takes place only during rainy periods, it is evident that the spores will probably find sufficient moisture to permit germination when they alight on the leaves. The germ tubes enter only the outermost layer of the leaf, the cuticle (Fig. 1, B), and probably derive most of their nourishment from the epidermal cells just beneath. After securing a foothold beneath the cuticle, the germ tube branches and forms a dense mycelium, giving rise to the brownish spot evident to the naked eye about ten days after infection. From these dense masses of mycelium the conidiophores, or spore stalks, are sent up in a columnar mass and from them the conidia arise (Fig. 1, B). The cuticle above these has either been previously dissolved by the action of the fungus or is ruptured by the crowding upward of the spore-forming elements. The spores are thus exposed and are easily carried by various agents to other leaves and to the fruit, where infection takes place in a manner similar to that described for the ascospores.

Control.—The time and condition attending the discharge of ascospores in the spring is a matter of great importance, since it is at this period that primary infection takes place. It is evident that if it were possible to prevent this primary infection the disease could be controlled without further effort.

Sprays applied just previous to the discharge of ascospores in the spring should effectively control the disease by preventing the first infection. Unfortunately it has been found that the discharge of ascospores takes place over a period of several weeks and may thus bring about infection at any time suitable for germination of spores. But the facts remain that ascospore discharge takes place only dur-

[1]Under this heading the life history of the causal organism will be given. For definitions and explanations of technical terms used in this and subsequent descriptions consult Introduction, page 2 to page 8, and Glossary, page 148.

ing rainy periods and that such rainy periods are necessary for germination of the spores. It is possible to forecast the weather with sufficient accuracy to apply a spray a day or so in advance of the first period when spore discharge is to be expected.

The results obtained by Wallace in New York, extending over several years, indicate that the first discharge of ascospores takes place during the first rainy period in May, while Childs in Oregon found that during the season of 1916 ascospore discharge took place as early as March 20 but was most abundant during a rainy period about the middle of April and again during the first week in May.

TABLE 1.—DATES OF SCAB INFECTION IN ILLINOIS

Year	Place	Observer	Date of first appearance	Probable dates of ascospore discharge
1898	Urbana (?)	Clinton	May 2	Apr. 18–25
1899	Urbana	Clinton	May 5	Apr. 21–28
1900	Urbana	Clinton	May 11	Apr. 27–May 4
1910	Neoga	Watkins	May 16	May 1–8
1911	Neoga	Watkins	About middle May	May 1–8
1912	Neoga	Watkins	About middle May	May 1–8
1912	Griggsville	Gunderson	May 15	May 1–8
1915	Neoga	Brock	May 17	May 2–9
1916	Neoga	Brock	May 17	May 2–9
1917	Neoga	Brock	May 20	May 9–16
1919	Urbana	Anderson	May 4	Apr. 20–27

Wallace and others have proved that the period between inoculation and the appearance of the fungus, called the incubation period, is from eight to fifteen days. Table 1 shows the date of the first appearance of scab in Illinois as recorded by various observers and the dates between which infection would have taken place according to the estimate of incubation made by Wallace.

While it seems theoretically possible entirely to prevent inoculation in the spring by destroying all old leaves by burning them or plowing them under, it has been found unsafe to depend completely upon this method for control in practical work. In the first place, every leaf would have to be destroyed. A single leaf with the perithecia of the fungus present is able to discharge thousands of spores in a few minutes, and a few of these alighting on the new leaves would be sufficient to start the primary infection, from which millions of conidia could be produced for future infections. In the second place, the orchardist often desires to leave a cover crop on the orchard over winter, and this would seriously interfere with any attempt to get rid of the old leaves. The application of a spray at the time necessary to prevent primary infection is less expensive than an attempt to completely destroy all the leaves, and such a spray serves also to control certain insects and possibly other fungous diseases.

It is possible to control scab successfully by the proper application of either lime sulfur or Bordeaux. Lime sulfur is being used by most orchardists for both the first and the second summer sprays. Under ordinary conditions the first summer, or pre-bloom spray, should anticipate the discharge of ascospores and thus prevent primary infection. The important factor governing the effectiveness of this spray is the condition of the weather. If possible, the spray should be applied just preceding a rainy period, since the first discharge of ascospores will probably take place during this period and the spray *must be on the leaves before the ascospores germinate* in order to be of any value whatever.

For the time of application of sprays see spray schedule for apples, page 113.

BLOTCH

Apple growers in the southern portion of the Mississippi valley have in apple blotch a disease more serious than scab, more uniformly present, and as hard to control as bitter rot. Fortunately, like scab, this is a superficial disease and its chief damage consists in impairment of the quality of the fruit.

Origin of the Disease.—Among pomaceous fruits blotch is known to occur only on the apple. The native species of crab apple also are subject to the disease, but it is still an open question as to whether blotch originated on the wild species and was transferred to the introduced species of apple, or whether it came from some other native host. It was found on leaves of wild crab and on apple fruit as early as 1895. For a number of years orchardists and horticulturists confused this disease with scab, and to this failure to distinguish the two diseases, rather than to rapid dissemination, was due its supposedly sudden appearance in many widely separated localities.

Loss from Blotch.—In the southern Mississippi valley loss from blotch is undoubtedly greater than from scab. It is greatest in Arkansas, Missouri, and Kansas, but in southern Illinois and Indiana south of latitude 40 degrees there is a serious annual loss. It is estimated that the annual loss in Clay county, Illinois, alone is $50,000.

The disease is not now severe in the northern or western fruit sections of Illinois, but it seems to be advancing northward. A few years ago blotch was unknown in central Indiana north of a line running thru Indianapolis. During the last five years the writer has observed its first appearance in a number of orchards north of this line which previous to this time were entirely free from it. In a like manner fruit growers in central Illinois have spoken of its entrance into their orchards within the last three or four years. The disease is not known outside the United States.

Blotch is found on the fruit, twigs, and leaves. It is also evident on the older limbs in the form of roughened bands on the bark (Fig.

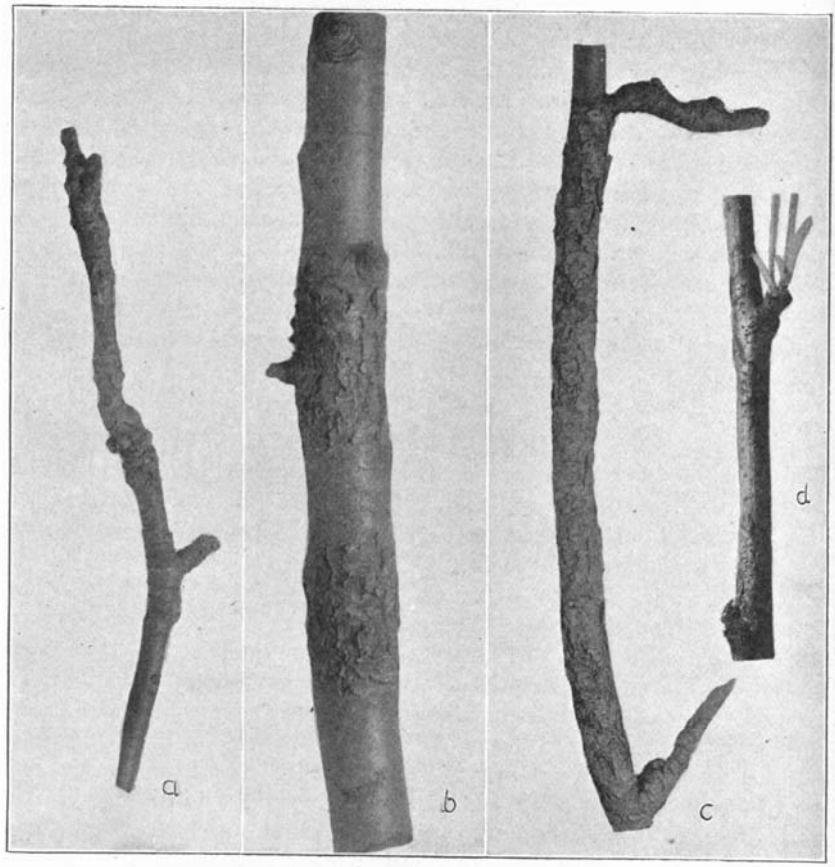

FIG. 4.—BLOTCH: (a) ON FRUIT SPURS; (b) OLD CANKERS ON LIMBS; (c) ON YOUNG BRANCH OF DUCHESS, SHOWING ROUGHENED BARK; (d) ON WATER SPROUT, SHOWING PYCNIDIA OF THE FUNGUS ON ONE- AND TWO-YEAR-OLD LESIONS

4, b). It causes the most serious damage on fruit but on varieties especially susceptible to its attack, such as Oldenburg and Missouri Pippin, it may cause the death of fruit spurs or even small branches, and thus materially reduce the yield of fruit. The damage to the leaf is not serious since the spots are always very small and do not cause defoliation. Occasionally the leaf petiole is seriously infected.

Symptoms.—On the fruit, the nature of the spot varies with the time and severity of infection and with the variety of fruit. The spots may be slightly sunken, raised, blister-like, or level with the surface of the apple and diffused (Fig. 5 and Plate II, d, e,). In all cases, however, the appearance of the young spots is much the same.

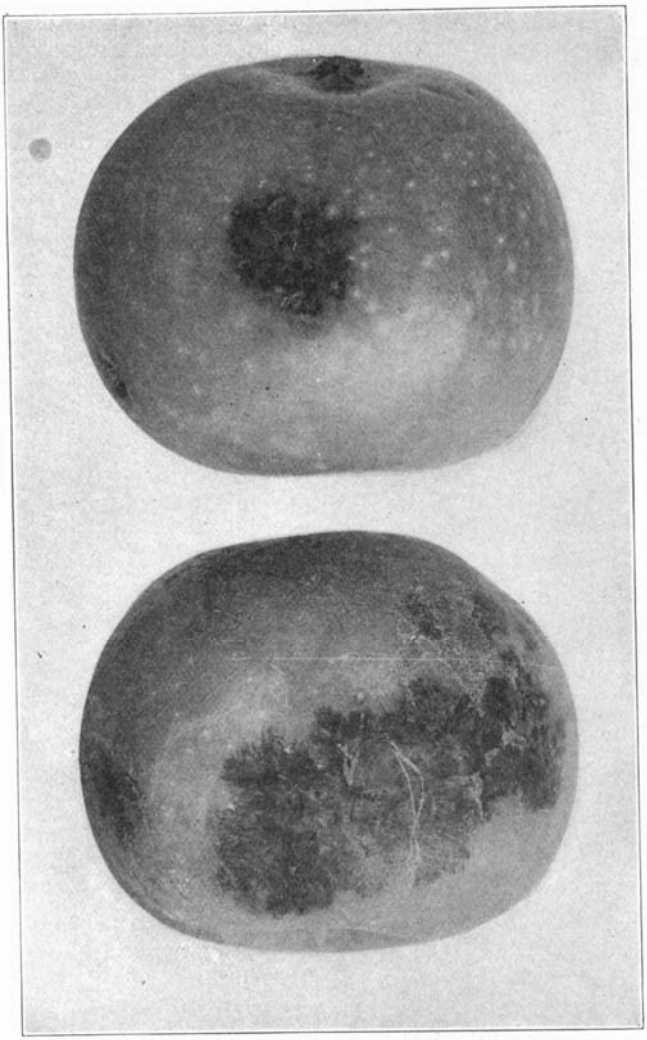

FIG. 5.—BLOTCH. ABOVE, A PITTED TYPE SHOWING PYCNIDIA IN THE PITS; BELOW, A SPREADING TYPE. NOTE THE FEATHERY EDGE OF THE ADVANCING BLOTCH SPOT

They appear as small, irregularly-edged masses of dark brown fibers beneath the cuticle of the fruit. As the spot becomes older the central area becomes black, with radiating strands which give the entire blotch a fringed appearance. In some cases the spot remains quite small and the feathery edge is not so evident. The lesions frequently have a stellate (starlike) appearance, which is due to the strands of hyphae radiating from the central area.

As the apple grows, the effect on the fruit and blotched area varies with the severity of infection, climatic conditions, and variety. Severe infection, such as is frequently found on Ben Davis, results in checking the growth of the apple beneath blotched areas and in consequent cracking. The most frequent type of injury is a cross-like crack which extends deep into the flesh of the fruit (Plate II, e). On Duchess the fruit does not ordinarily become deformed but, developing in a regular manner, disperses the blotch. In some cases, when the fruit is mature the disease is evident only in slightly discolored areas usually darker than the surrounding tissue. On some red varieties the same reaction takes place and the original blotch is almost impossible to detect. On the Missouri Pippin, Arkansas Black, and a few other varieties, infected areas later become pitted and sunken.

One of the distinguishing characters of this disease is the presence, at or near the center, of small black pimples. They develop a short time after the spot becomes evident on the fruit. The blotch spots are easily distinguished from scab in that blotch always presents a slick, shiny appearance, while scab spots on the fruit are always dull and velvety. The irregular, feathery edge of the blotch is also a distinguishing character, especially in the early stages of the disease, altho, as mentioned above, there are exceptions to this condition. The name "blotch" is a particularly good term for this disease, as it is descriptive of the lesions produced.

On twigs, superficial cankers are produced. These are especially evident on water sprouts (Fig. 4, d), but most numerous and destructive on fruit spurs (Fig. 4, a, c). If the disease is present in an orchard, it is most surely and quickly found by examining any water sprouts which may be present. The cankers are not evident from infections of the current year, except upon close examination late in the season, when they appear as small, olive-brown spots. The following season, however, the spots on the twigs are very characteristic. The central area is usually slightly raised, light tan in color, with scattered pimples over the surface. Surrounding this is the reddish brown area of the current year's development. The central, tan-colored area with its dark pimples is one of the most characteristic diagnostic features. The spots on the water sprouts and on fast-growing twigs are much larger and more evident than on the fruit spurs and slower-growing wood. There is also some difference in color in the two cases.

In subsequent seasons the blotched areas on twigs appear as rough, cracked bands, giving the limb a chapped appearance (Fig. 4, b). As the branch grows older, evidence of the blotch remains in the form of slightly roughened bands. Frequently the history of the disease for ten or fifteen years can be traced by these bands. The old bands

give the quickest and easiest method of determining whether or not blotch is present in a locality, unless it has been recently introduced. On fruit spurs and on slow-growing wood, the closeness of successive years' infections gives the whole twig a very rough appearance, and the banding is not so evident.

On the leaves, numerous small, light gray spots are produced (Fig. 6). These are scarcely ever over one-sixteenth of an inch in diameter, and the central area does not fall out altho it soon dies and becomes papery in texture. Usually there is a single black dot near the center of each spot on the leaf.

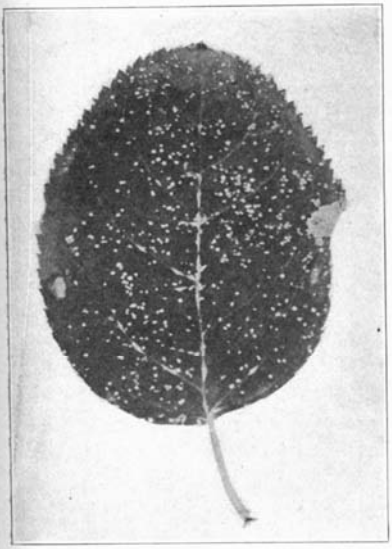

FIG. 6.—Blotch spots on apple leaf

Cause.—Blotch is caused by a fungus, *Phyllosticta solitaria.*

This fungus winters in the mycelial state in cankers on twigs. In the spring, pycnidia are matured beneath the surface of the bark. Within the pycnidia, spores are formed in great numbers and these ooze up thru the ostioles into the air, especially during damp weather. The spores begin to exude from two to six weeks after the petals fall. These spores are carried by water, wind, and insects to the fruit, to other twigs, and to leaves, where germination and infection take place. On the apple, new pycnidia are formed (Fig. 5) and these in turn exude spores. Spores in twig cankers continue to be produced for several weeks, but by midsummer most of the spores have been discharged. Within the spots on the leaves pycnidia are formed, but according to most authorities remain sterile, that is, no spores are produced.

Spores from fruit or twig pycnidia are carried, as previously mentioned, to the twig growth of the current year and there produce new cankers. These cankers in turn serve to carry the fungus over winter in the mycelial state. Hence there is no need of winter spores, as in the case of apple scab, and no such stage has been discovered.

Control.—Blotch can be controlled by summer applications of Bordeaux or lime sulfur. The first blotch spray is that usually applied three weeks after the fall of the bloom.[1] This is the most effective

[1]For early varieties such as Oldenburg an earlier application than here recommended is deemed necessary.

spray as it is applied just before the maximum exudation of spores is to be expected. The second blotch spray is the one applied five weeks after the bloom. These are the third and fourth summer sprays as indicated in the spray schedule on page 113.

One of the most important points in controlling blotch is continuous care of the orchard. Trees properly sprayed year after year are kept fairly free from cankers on limbs, and thus sources of infection are very materially reduced. For the same reason all water sprouts and extra branches should be removed *each year.* This not only opens up the tree so that spray mixtures are more effective but also reduces the surface on which the fungus can gain a foothold for hibernating.

To prevent twig infection, it is a good plan to spray young trees of susceptible varieties, such as Oldenburg, from the time they are set in the orchard. This will reduce the labor of control later in the life of the orchard. For the same reason spraying should be practiced when there is no set of fruit on the trees.

BITTER ROT

Among the pomaceous fruits affected by bitter rot are apple, pear, and quince. The disease occurs upon a large number of other plants but is of economic importance only as affecting the apple and the quince.

Loss from Bitter Rot.—No disease is more dreaded by the apple growers of Illinois than is bitter rot. The sudden appearance of the disease in an orchard when the fruit is almost ready to harvest, its rapid spread, and its destructiveness are disheartening in the extreme. Cases are common where a buyer has purchased the fruit of an orchard when almost mature and, returning in a few weeks to harvest, has found more than half the crop completely destroyed and the remainder imperiled. In moist, hot summers this disease is almost sure to be found in the more southern orchards, and in some regions it is regarded as the most serious apple disease.

The disease occurs only on the fruit and the branches. The rotting of fruit is the only source of financial loss, since twig infection rarely causes death or serious injury.

Origin and Distribution.—Bitter rot is found in Europe but is not at all serious there. It is probably of American origin as it occurs on a number of native wild plants. It has been known in this country since 1867. The disease is found in most of the apple-growing regions of the United States, but rarely occurs in the northern or western sections. It is most destructive in the region south of 39° 30′ north latitude. The states suffering most severely are West Virginia, Virginia, Maryland, North and South Carolina, Kentucky, Tennessee, Illinois (southern), Arkansas, Indiana (southern), Missouri (southern), Oklahoma, and Kansas.

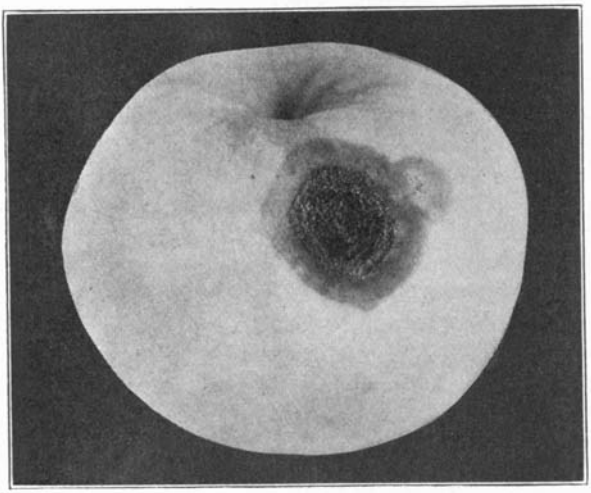

FIG. 7.—BITTER ROT ON APPLE, SHOWING CIRCULAR CHARACTER OF SPOT AND CONCENTRIC FRUITING PUSTULES OF THE FUNGUS

Susceptibility of Different Varieties.—There are no varieties of apple immune to the disease, altho some varieties are more severely attacked than others. The most susceptible are: Lowell, Willow Twig, Huntsman, Yellow Newton, and Ben Davis. Moderately susceptible varieties include Jonathan, Grimes, Stark, Northern Spy, and Delicious; those most resistant are Winesap, York Imperial, Janet (Ralls), Minkler, Rome Beauty, Salome, Aikin, and all early varieties. It is probable that the early varieties escape the disease rather than that they show any marked resistance.

Symptoms.—The rotted spots on the fruit may appear at any time from June to September, altho the disease rarely becomes serious before the middle of July. Tho often spoken of as "ripe rot," bitter rot is not confined to mature fruit but may occur on half-grown apples. The most favorable condition for the development of the disease exists during hot, damp weather when the fruit is nearing maturity. On this account the period between the middle of July and the first of September is the most favorable season for bitter rot.

The rot first appears on the fruit as a small, light brown spot which gradually enlarges, always retaining a perfectly circular outline (Fig. 7). The rotted area remains firm in texture and while still quite small becomes sunken, forming a saucer-shaped depression. It becomes darker as it increases in size, and the margin remains sharply defined. The sunken condition of the spot, its definite circular outline, and its firm texture easily differentiate this rot from any other, even before the appearance of the spore masses. The number of spots on a single fruit varies from one to several hundred. In severe in-

fections it is common to see fruit fairly covered with the small, light brown lesions.

When the spot has attained a diameter of one-fourth to one-half inch, small raised blisters appear on its surface near the center (Fig. 7). Later the skin is ruptured, and glistening pink cushions appear. At this stage the spot is almost black and the contrast between the pink cushions and the dark background is very striking. When the weather is dry and there are no heavy dews, the cushions do not break thru the epidermis until the lesions are quite large. As the spots enlarge, more pustules appear and these are frequently arranged in a rather definite series of concentric circles (Fig. 7). The rot ultimately involves the entire apple, and if not complicated by other rots the fruit remains rather firm in texture but somewhat shrunken and wrinkled. In most cases infected apples fall before this stage is reached, but frequently the mummied fruit remains attached to the spur and clings to the tree thruout the winter.

Cankers are formed on branches that are from two to fifteen years of age. They are comparatively rare in Illinois orchards and are easily confused with blight cankers. The diseased area is usually oval in outline and slightly sunken below the surrounding bark. The bark is entirely dead, while the wood below is brown and appears dead and dry. A zoned appearance is produced in old cankers by cracks in the bark which run parallel to the edge of the cankered area (Fig. 8).

FIG. 8.—BITTER ROT CANKER

(Photograph from U. S. Department of Agriculture)

Cause.—Bitter rot is caused by a fungus, *Glomerella cingulata.*

The mycelium of this fungus grows beneath the skin, or epidermis, of the apple and feeds upon the nutritive substances in the cells of the fruit. If a bit of the brown pulp is removed and examined under a microscope, small, branching threads (the hyphae) can be seen running between the host cells. These hyphae extend into the healthy tissue and break it down as they advance. After a time a mass of these hyphae collect in a circle near the center of the spot just beneath the epidermis and send up short stalks (conidiophores) on the ends of which

the spores (conidia) are produced. These are formed in great numbers and gradually push the epidermis upward, which accounts for the blister-like areas seen in the diseased spots.

The masses of spore stalks and the cushions of hyphae from which they arise are called acervuli (singular, acervulus). As more and more conidia are produced on the stalks (conidiophores) the epidermis is finally ruptured and the spores are seen in pink, gelatinous heaps. These conidia are surrounded by a gelatinous substance which gives them a glistening appearance when freshly exuded. If the surface of the fruit becomes dry, the gelatinous material becomes quite hard and horny. When water is added to the mass of spores, this substance dissolves and the spores are more easily separated.

These summer spores, or conidia, are washed from the fruit and drop on other apples or are carried by insects from one fruit to another. If the weather conditions are favorable when they alight on the surface of another apple, they germinate just as a seed of wheat would germinate if placed in warm, moist soil. They send out a delicate thread, called a germ tube (Fig. 1, D), which is able to penetrate the uninjured skin of the apple and start a new spot. The period elapsing between infection by the germ tube and the appearance of a spot which can be seen with the unaided eye (the incubation period) varies according to the weather. If weather conditions are most favorable, the spots may appear in a week or sooner. These lesions increase in size and, in turn, acervuli are produced from which spores are supplied for new infections. This process may continue thruout the summer if the weather is favorable. Cold days, or very dry weather without dew at night, usually check the spread of the disease.

If these summer spores alight on a twig where it has been injured or where other cankers have started, they enter the tissue of the branch and may grow in the living tissue, forming cankers. The fungus also grows in cracks in the bark, on dead branches, and on old leaf or fruit scars on spurs. In fact, it appears to develop on any portion of the host where it can secure sufficient moisture and food material to keep it alive.

The question of the primary infection of fruit in the summer has always been of great interest. The sudden appearance of thousands of infected apples in a few days during a sultry, damp period in July or August is a common occurrence. Since the conidia produced on the fruit during the previous season are not able to survive the winter, and since the winter-spore stage is of rare occurrence, it is evident that the fungus must live over in the vegetative, or mycelial, stage and produce new crops of summer spores the following year. Early investigations by Clinton, Burrill, and others in this state proved that the fungus is able to live over winter in the mummied

fruit which hangs on the trees. Subsequently cankers of bitter rot were observed and it was established that these are able to develop masses of spores in the summer and start an epiphytotic of rot. But altho these cankers are found abundantly during some seasons, they are rare or wanting in other years when the disease is very prevalent. Finally it was found that the fungus may live over in numerous scars, old cankers, etc., which fact would seem to explain the sudden, widespread, simultaneous appearance of rotted apples in an orchard.

In addition to the summer stage there is produced a winter-spore stage similar to the winter-spore stage of apple scab, described in the introduction, except that the perithecia, or ascus-bearing chambers, are produced in the old cankers, or occasionally on mummied fruit. This stage is not important in the life history of the fungus from an economic aspect and it will not be described.

Control.—The important points to be remembered in attempting to control this disease are: (1) The fungus winters on dead branches, old cankers, and mummied fruit. (2) Hot, damp weather in July and August usually starts an epiphytotic of bitter rot, while cold or very dry weather holds it in check. (3) The rot appears from several days to more than a week after the actual infection, and infected fruit cannot be saved by spraying or any other means. (4) After the primary infection the spores of the fungus are spread rapidly and widely, soon producing a general infection.

Bitter rot is one of the most difficult diseases to control if the weather is at all favorable for its spread. The orchardist should watch the weather and, when bitter rot is anticipated, should be prepared to fight it by all the methods described below.

Hand Picking.—Most commercial orchardists have had sufficient experience with bitter rot to recognize it when it appears. During July and August frequent trips thru the orchard should be made by someone well acquainted with the disease, to locate the first rotted fruit. Frequently year after year a certain tree or group of trees in an orchard will be the first to show bitter rot on their fruit, and experienced orchardists soon learn to look upon these trees as a barometer for the appearance of the disease.

When discovered, the rotted fruit should be picked carefully by means of a pole picker. It should not be knocked down, as this serves to distribute the spores. It is also important that the fruit be picked in the early stage of the rot before the spores have appeared on the surface. The picked apples should be collected in a bucket, taken from the orchard, and buried.

Care in picking the first rotted fruit often saves hundreds of bushels of apples, but a little carelessness in overlooking a few apples on a tree may mean the loss of all the fruit on that and neighboring trees.

Spraying.—Hand picking should not be substituted for spraying except under exceptional conditions. Spraying and hand picking combined are needed to keep the disease in check. It is essential *to spray before the disease appears* since it is almost impossible to hold it in check after a good infection has started in some part of the orchard. The number of sprays and the time of the first application depend largely upon weather conditions and somewhat upon the severity of the disease in former years. The first application should be made about July 1. For protection against bitter rot, Bordeaux has proved the most successful spray (see page 12 for preparation). The second and third sprays should be applied as indicated in the spray schedule, page 113.

General Sanitation.—Since the fungus lives over winter in the dead or cankered branches and in the mummied fruit, a serious source of infection can be eliminated if all dead wood is removed and the cankers treated as directed under blister canker. This treatment reduces the chance of infection but cannot remove all possible sources, since the fungus may live over winter in fruit scars or crevices in the bark.

BLISTER CANKER

Loss from Blister Canker.—The loss from blister canker is especially great in Illinois because the orchards of the state are so heavily planted with Ben Davis, the variety most susceptible to this disease. Ben Davis constitutes over one third of the total apple crop of the state, and the average twenty-year-old Ben Davis orchard shows 20 to 40 percent of the trees infected and 5 to 10 percent dead, while the living infected trees have from one to several large limbs dead.

A low estimate would place the annual loss of Ben Davis, Delicious, Willow Twig, and Gano, the four most susceptible varieties, at 1 percent of the crop. The average yearly production of these varieties in Illinois is about 3,000,000 bushels, and the average price during the past five years has been approximately one dollar a bushel. Thus, the annual loss in this state is between $25,000 and $30,000. At present there is a very large acreage of Ben Davis which is over twenty years old and the financial loss from these orchards will be very heavy during the next decade. Fortunately the younger orchards have been planted with other varieties not so susceptible to blister canker.

Origin and Distribution.—In this country the first published account of blister canker as a serious disease of apple trees was by Hasselbring, in Illinois, in 1902. Undoubtedly the disease had long been present in orchards of the state but no particular attention had been given to it previous to that time. Since that date the disease has been reported as serious in Missouri, Illinois, Indiana, Oklahoma, Nebraska,

Iowa, Kansas, Colorado, and Ohio. It is also present in a number of other states and in several foreign countries, but is nowhere so serious as in the Mississippi valley.

Susceptibility of Different Varieties.—Ben Davis, Delicious, and Gano are notoriously susceptible to the disease, while Willow Twig, Grimes, Rome Beauty, Maiden Blush, and Wealthy are moderately susceptible.

Symptoms.—It is usually impossible to identify blister canker definitely until an advanced stage has been reached. The appearance of the canker in its earlier stages may easily be mistaken for cankers and injuries caused by other agents. It is only when the characteristic "blisters" of the imperfect stage, the "nail heads" of the perfect stage, or the peculiar mottled appearance of the bark appear, that a sure diagnosis is possible by one who has not had

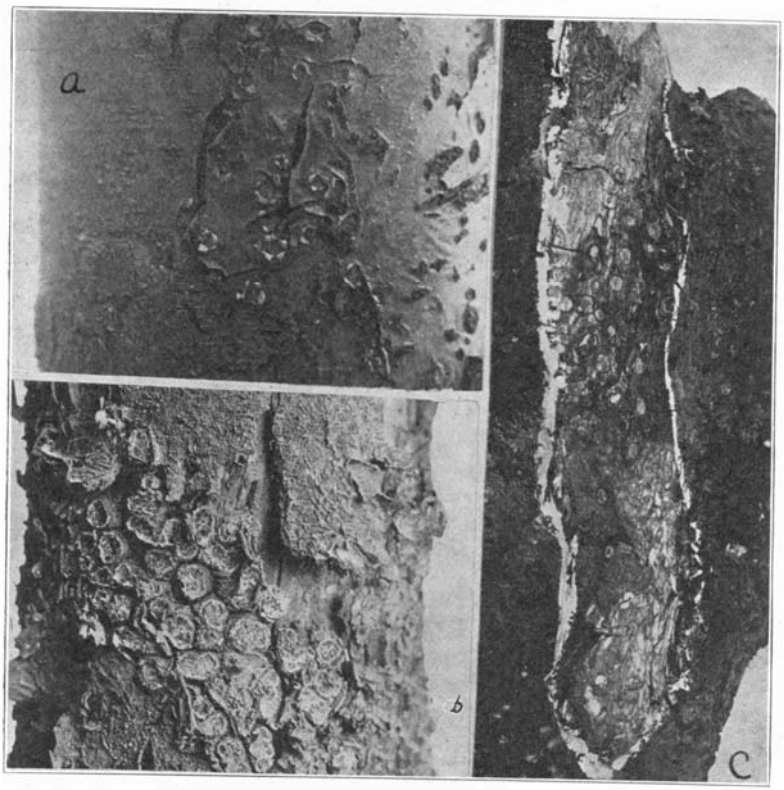

FIG. 9.—BLISTER CANKER: (a) "BLISTERS" SHOWN WITH ROLLED-BACK EDGES EXPOSING DUST-COLORED MASSES OF SPORES; (b) "NAIL HEADS" OF PERFECT OR WINTER STAGE; (c) MOTTLED INNER BARK SHOWING BLACK RINGS OF SECTIONED "BLISTERS"

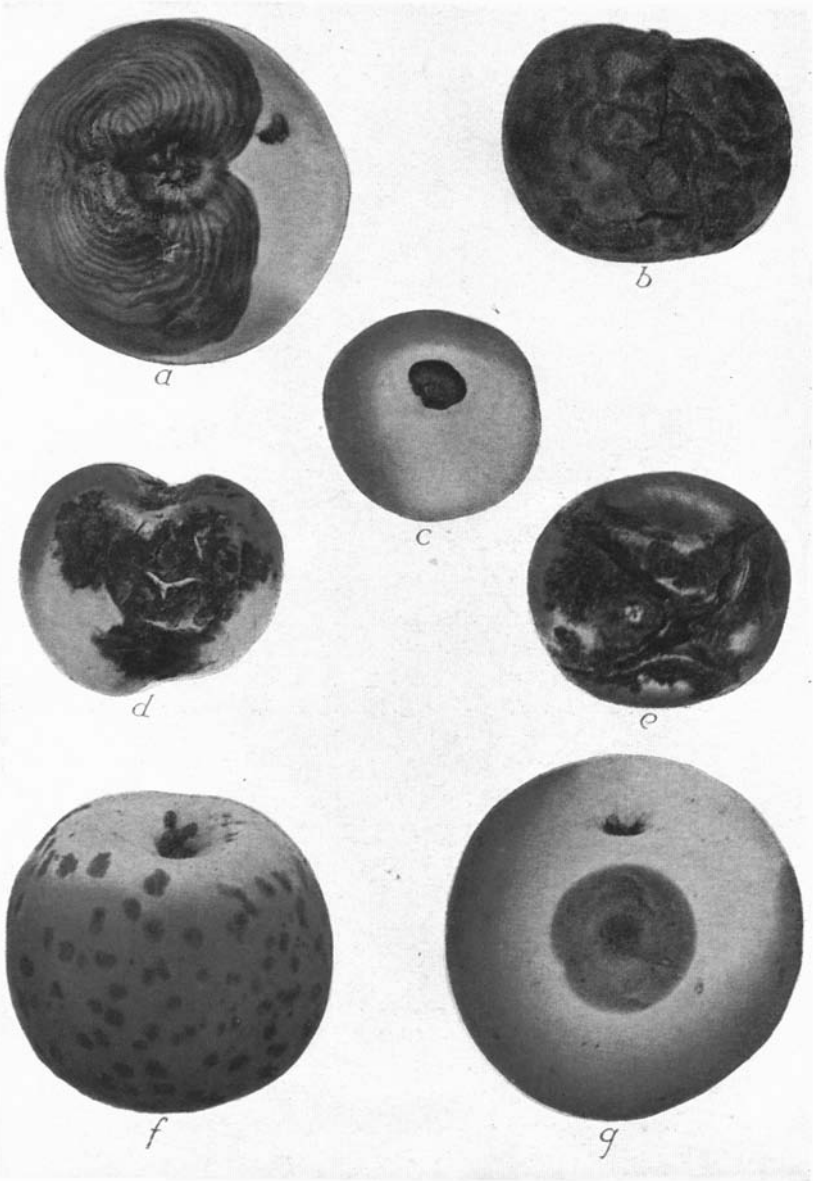

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PLATE II.—TYPES OF APPLE FRUIT DISEASE

(a) Black Rot Showing Pycnidia; (b) Advanced Stage of Black Rot; (c) End Rot Due to Spray Injury; (d and e) Blotch; (f) Jonathan Spot; (g) Volutella Rot

more than the usual experience with this disease. The fact that the disease progresses more rapidly in the wood than in the bark accounts in part for the absence of definite external symptoms previous to the rather sudden appearance of a well-developed canker. The first evidence of canker is the darker appearance of the bark above the diseased area. The area so afflicted may be rather large owing to the internal nature of the disease. When this bark is cut in such a way as to expose the brown cortex, a characteristic mottled appear-

FIG. 10.—BLISTER CANKER OF APPLE

Between a and b the outer bark has been cut away exposing the mottled inner bark. In the area around c the open "blisters" are evident. At d the dead bark has weathered away exposing the "nail heads," while at e they have not yet broken thru.

ance is noticed (Figs. 9, c and 10). This is the earliest definite indication of the nature of the trouble. The canker at this time may extend from six inches to two feet along the branch and be from one to six inches across its short diameter. The edges of the canker are not well defined and the area involved is only slightly sunken.

In the summer, blister-like protuberances, which give the name to this disease, make their appearance over the surface of the cankered area. These are at first only slightly raised, about one-fourth inch in diameter, and circular in outline. On smaller limbs which have been killed in a single season they may appear over the entire surface. On old cankers they appear only at the edge. Later in the season these blisters split open in a star-like manner, and the ruptured segments roll back upon themselves, exposing a grayish tan, powdery interior (Fig. 9, a). By cutting into the bark over a cankered area, black circles around a wood-colored center may be observed (Fig. 9, c). This is a sure indication of the nature of the disease.

On older parts of the cankers, circular or somewhat irregular bodies from one-eighth to three-eighths inch in diameter may be observed (Figs. 9, b and 10). These are the "nail heads" which give the disease one of its common names. As the dead bark wears away, these "nail heads," on account of their hardness and connection with the wood beneath, remain as protruding, black, cylindrical studs, altho, when first formed, their surfaces are almost level with the surrounding bark. The top of the "nail head" is concave and either coal black or ash gray in color, depending upon the stage of development. Frequently the death of the limb takes place during the summer, so that in an orchard where this disease prevails many branches with withered leaves may be seen each season (Fig. 11).

Cause.—This disease is caused by a fungus called *Nummularia discreta.*

Like the apple scab this fungus has two stages in its life history—the perfect and the imperfect. Beginning in July the conidial or imperfect stage is produced on the blister-like areas already described. These conidia are produced in large numbers and are the grayish tan, powdery masses previously described. They may be carried by wind, water, or insects to various parts of the orchard, where, under favorable conditions, they may start new cankers. It is probable, however, that the conidia do not play so important a part in infections as do the ascospores.

Following the production of conidia, the stroma upon which the conidia are produced begins to develop chambers (perithecia) in which the perfect or ascospore stage is developed. The asci are formed in enormous numbers and each contains eight dark, globular ascospores. Mature ascospores capable of infecting can be found in the perithecia at any time of the year but are most abundant in late

summer and autumn. The ascospores are forcibly discharged into the open air thru the neck of the perithecium. They are very light and may float about for some time in the open. They are carried by air currents to other trees in the orchard. This discharge takes place only when the bark and the base of the stroma are wet and in nature probably occurs only following a rain, but once started it may continue for several days regardless of the condition of the weather.

FIG. 11.—BEN DAVIS TREE ATTACKED BY BLISTER CANKER. THIS IS TYPICAL OF OLD BEN DAVIS ORCHARDS

These ascospores are the most important factor in infecting other trees. They germinate readily and are resistant to drying and cold. They are present thruout the year and may bring about infection at any season when conditions are favorable.

A peculiar thing about this fungus is the fact that it does not readily infect thru the bark or in young living tissue. It is primarily a wound parasite and grows best in wood that is from three to five years old. It cannot enter a sound limb, and when its spores are placed in direct contact with living tissue just beneath the bark they do not usually infect. It is thus evident that only large, deep wounds, or wounds produced by pruning large limbs, are dangerous. When ascospores, and to a limited extent the conidia, alight on such wounds, infection may take place. Frequently such conditions are brought about in pruning an orchard. A careless workman saws off a dead limb, dragging the saw thru several stromata. Thousands of

spores are thus spread along the entire surface of the saw. He next saws off a healthy limb on a neighboring tree, distributing spores on the damp surface of the stub. Here they germinate and enter the wood. Infection takes place most readily when the tree is making the least growth, provided other conditions are favorable.

Upon entering the wood the fungus evidently grows for some time in the woody parts, frequently going up or down for several feet before it finally makes its appearance on the surface. When the wood of a tree is invaded, it is rarely possible to prevent the spread of the disease in that particular tree. The distance thru which this fungus will travel in the wood has not been accurately determined but it is known to be at least several feet.

Control.—In attempting control measures it must be borne in mind that cutting the diseased bark away and treating the wound, or even cutting off a diseased limb, may not check the disease as in the case of more superficial cankers. When the fungus is once established in a tree, the chances are that it cannot be successfully cut out. If it happens to be localized in one limb, cutting may be effective. The disease can be controlled only by using proper sanitary methods from the time the orchard is started. The following precautions should be taken.

1. All tools used in pruning should be sterilized[1] before passing from one tree to another.
2. All large pruning wounds should be coated with a suitable protective paint and kept painted until healed.
3. All accidental wounds when large should be cleaned and painted.
4. All dead branches should be removed and the cut surface sterilized and painted.

In case some of the trees in an orchard become diseased, or if the disease is already well established, the following procedure is advised:

1. Cut off all cankered limbs when the canker is too far advanced to treat as described below. The limbs should be cut well below the cankered area and the exposed surface painted.

2. In case it is desired to save a large limb which is bearing fruit, or if the canker is on the trunk and not far advanced, the diseased area may be cut out and the bark removed slightly beyond the edge of the living tissue. The exposed wound should then be washed with a sterilizing solution, painted, and watched each year for the reappearance of the disease. If any cankers appear near the old wound or on the tree they should be treated at once. The object of

[1]Mercuric chlorid (corrosive sublimate) is one of the most convenient chemicals to use for sterilizing tools and tree surfaces. This chemical may be obtained from any drug store in the form of tablets. A solution of 1 to 1,000 should be used both for tools and for washing wounds. Directions for making this strength solution are usually given on the bottle. A convenient swab for washing tools and wounds is made by tying a rag or sponge on the end of a short stick.

such treatment is to prevent the development of the spore pustules and thus prevent the dissemination of the disease. Such trees frequently live many years and bear almost normal crops. The wounds frequently heal and, altho other cankers may appear, prompt treatment will usually keep the tree in a bearing condition. The oozing which frequently results when cankered trees are treated, prevents the proper healing of the wound and makes the painting of the surface difficult.

APPLE RUST

Loss from Apple Rust.—While apple, or "cedar," rust is one of the most common diseases of certain sections of Illinois it has never been considered of sufficient economic importance by growers to warrant extra efforts to control it. The orchards in the extreme southern end of the state and certain ones along the western side suffer the most serious loss. This is not so much because of peculiar climatic conditions as because of the general prevalence of cedar trees in these more or less wooded regions.

Leaves, fruit, and, rarely, twigs are affected by the disease. The loss comes thru the reduction in leaf surface owing to partial defoliation and spotting of the leaves, and thru the occasional infection of the fruit. There is also a decided stunting of trees that have been repeatedly attacked. It is difficult to estimate the exact financial loss but it certainly amounts to over $25,000 annually. There is evidence that cedar rust on cultivated apples is increasing in seriousness from year to year. It has been noticed also that the years in which epiphytotics of rust appear occur at rather regular intervals.

Distribution.—Apple rust is found thruout central and eastern United States but seems to be most destructive in the southern sections, especially in Virginia, Alabama, and West Virginia. It has also been reported as severe in Wisconsin, Iowa, Indiana, Illinois, Nebraska, Kansas, and Missouri.

Susceptibility of Different Varieties.—Varietal resistance to rust is more marked than in most fruit diseases. Some varieties, such as Grimes, seem to be almost entirely immune, while others, Wealthy, for example, are highly susceptible. In this state Jonathan, Wealthy, Benoni, Minkler, Rome Beauty, Smith Cider, York Imperial, and Red June are among the most susceptible, while Grimes, Duchess, Winesap, Stayman Winesap, Yellow Transparent, and Northwestern Greening are considered resistant. Ben Davis, Aikin, and Gano are moderately susceptible.

Symptoms.—On the leaves, the first indication of the disease is the presence of small, light yellow spots. These gradually enlarge and become bright orange in color (Fig. 12, b). The leaf tissue does not die but remains alive during the greater part of the season.

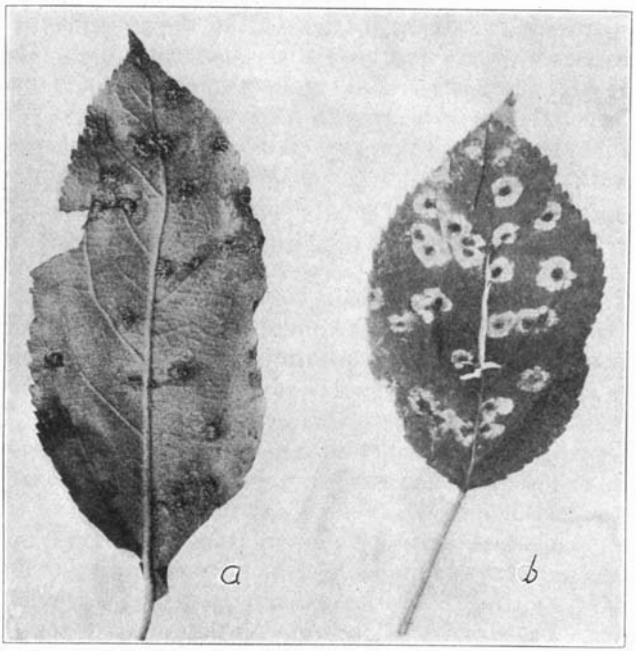

FIG. 12.—APPLE RUST ON LEAVES: (a) ON UNDER SURFACE; (b) ON UPPER SURFACE

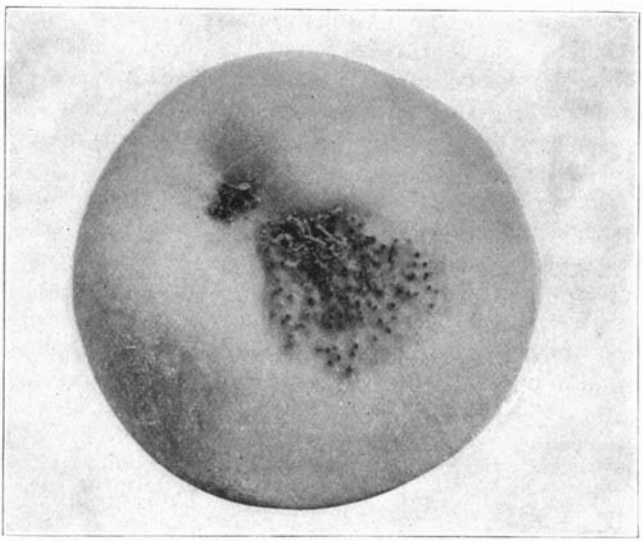

FIG. 13.—APPLE RUST ON FRUIT

In this respect this spot differs from all other foliage spots of the apple. A few weeks after the lesions become evident, minute black dots appear on the upper surface of the leaf near the center of the orange-colored area (Fig. 12, b). On the lower surface the tissues of the leaf swell into a convex cushion on which are produced, later in the season, a number of cup-shaped structures (Fig. 12, a) which, under a hand lens, show the edges curled back in a peculiar manner.

On the fruit, the diseased area has much the same appearance as on the leaf, but it is usually considerably larger. Here also cup-shaped structures are produced resembling those on the lower surface of the leaf (Fig. 13).

Cause.—Apple rust in Illinois is produced by *Gymnosporangium Juniperi-virginiana.* This fungus has a complex life history, which illustrates the necessity of a scientific study of fungous parasites as a foundation for control measures.

On the under surface of the apple leaf in the cup-shaped pustules, called *aecia,* there are produced numerous brown spores, termed *aeciospores.* These do not reinfect the apple but are carried in the summer to the branches of the red cedar, where they germinate and infect this host, producing large brown galls, or "cedar apples," the following year (Fig. 14). The cedar apples are abnormal growths of the tissues of the cedar brought about by the stimulation of the fungus mycelium. These galls continue to grow until they are sometimes two inches in diameter, altho the usual size averages about an inch. Frequently ten or more such galls are seen on a single branch of a cedar tree in the neighborhood of an orchard.

The cedar apples rest during the second winter following infection. In early spring of the next season the surface becomes pitted, and in the latter part of April long gelatinous horns grow out from these pits (Fig. 14). These horns contain another type of spore, which is borne on the end of a long gelatinous stalk. This is a dark-colored, two-celled, rather thick-walled spore, termed a *teliospore.*

Teliospores are produced in enormous quantities in each of the horns. During wet weather these horns become very soft and gelatinous and much swollen, while during dry periods they are rather firm, dry, and much smaller. During rainy periods the teliospore germinates, producing from each cell, a short club-shaped stalk (the basidium). From this stalk, which is divided into four cells, there are produced minute colorless spores on the ends of short, sharp projections, one from each cell. These are called *basidiospores* or *sporidia.* They in turn are carried to the upper surface of the apple leaf or fruit and under favorable conditions germinate and produce the yellow spots already described. This infection takes place only during the rainy periods following the production of the horns, because the germination of the teliospores is dependent upon the gelatinization of these

FIG. 14.—CEDAR APPLE WITH SPORE HORNS DEVELOPED BUT DRY

FIG. 15.—CEDAR APPLE WITH SPORE HORNS MOIST AND EXPANDED

horns, which occurs only in wet weather. Furthermore it has been discovered that the basidiospores are able to infect only the young leaves of the apple, the older leaves being entirely immune. This is the reason why only a few leaves on a branch will be heavily infected while all above and below the particular region have entirely escaped. Unfortunately each successive rainy spell during several weeks may bring about infection, since all the spores in the horns do not germinate at one time.

Control.—Control measures are based upon the fact that the fungus cannot continue to live unless it is able to go to the red cedar. The aeciospores from apple trees cannot reinfect the apple but must pass to the cedar. It is evident, therefore, that the elimination of the cedar is the easiest method of control. It has been found that the spores from the cedar may be carried a mile, altho serious infection rarely occurs where the cedars are over a half mile from the orchard.

Since the cedar is of far less economic importance than the apple and since other trees can be used as satisfactorily for ornamental purposes and wind breaks, it is evident that the cedar should be removed from all orchard regions. In Illinois this would not be a serious or costly proposition at the present time. In only a few localities are cedars grown to any great extent for ornamental purposes, while the small cedar trees which appear in wood lots and fence corners

are of no economic importance and are frequently not desired by the owner of the land. As a rule it is possible for the owner of an orchard to obtain the consent of his neighbors to dig out such cedars as occur in their wood lots, and an effort should always be made to secure this voluntary action. There is a law in this state compelling the removal of plants which harbor disease and, in case of serious opposition on the part of those owning cedars in the neighborhood of orchards, this law can be enforced. It is rarely necessary, however, to call upon the state to see that such measures are taken, and it is strongly urged that every other means be employed to bring about a voluntary removal of the cedar.

Some success has been obtained by spraying for control of rust. This should be attempted only where it is entirely impracticable to eradicate the cedar. Effective control depends upon close attention to the behavior of the cedar apple. Because of the nature of the life history of the organism, it is evident that the spray must be applied in time to anticipate the infection of the apple leaf by the transfer and germination of the spores (basidiospores) from the horns of the cedar apple.

Since the spores are produced only in wet weather, the first spray should be applied *before* the first wet period following the emergence of the spore horns from the cedar apple. In Illinois this occurs about the first of May, but no fixed date can be given. The second spray should be applied as soon as the first spray has been washed off, and again preceding a rainy period, if possible. The spore horns are largely exhausted by the last of May and no infection need be feared after that date.

Bordeaux mixture and lead arsenate have been found most effective as a spray, altho lime sulfur markedly reduces the amount of infection. It is probable that the sprays as made for the control of scab and curculio in this state very materially reduce the amount of rust, altho in sections badly infected and on susceptible varieties, this disease does a great deal of damage even when the regular sprays are applied.

In planting a new orchard the probability of rust infection should always be considered. If an orchard is to be planted in a region where red cedars commonly occur, only those varieties should be planted which are *known* to be highly resistant to the rust. Such varieties as Wealthy, Red June, and Smith Cider should *not* be planted under such conditions. The orchardist has a sufficient choice among the resistant varieties.

FIRE BLIGHT OF APPLE

Fire blight is often referred to as "twig blight" when it attacks twigs of the current year, or "blossom blight" when it is especially

destructive to blossoms. The term "spur blight" is used when the blight extends from blossoms or young fruit down into the fruit spur, killing the leaves beneath the blossom cluster. "Blight canker" is a term used to distinguish the canker produced by this disease on the branches and bole.

Origin of the Disease.—In the early numbers of the *Transactions of the Illinois Horticultural Society,* fire blight is among the diseases most frequently mentioned and has evidently been a well-recognized disease since the beginning of commercial orcharding in this state. It was described as early as 1794 in the Hudson valley. It is re-

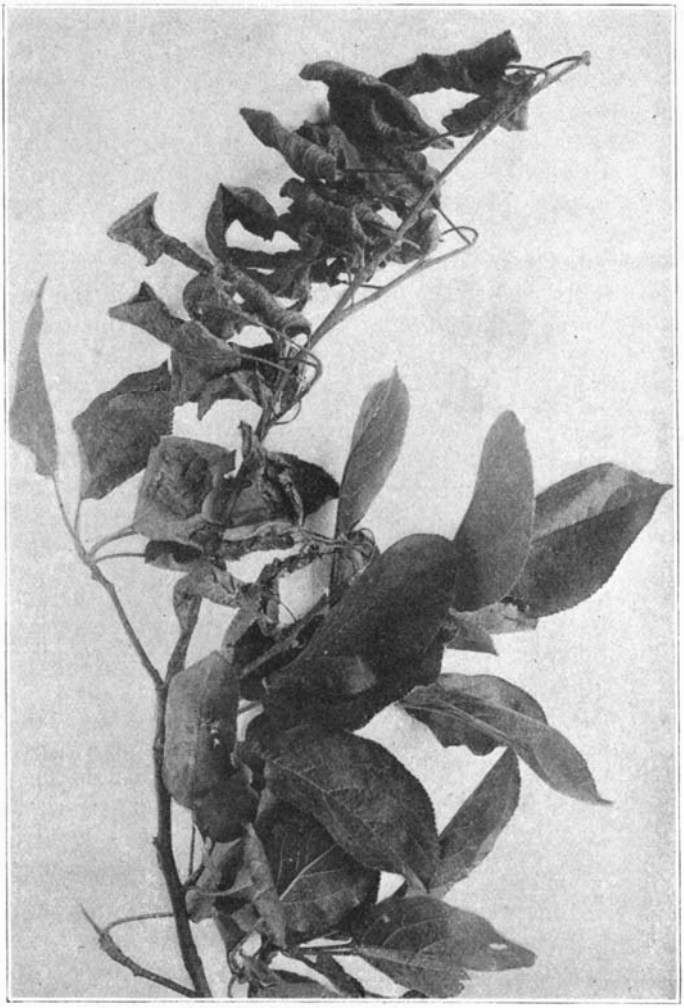

FIG. 16.—TWIG BLIGHT OF APPLE

garded as most destructive, especially on pears, in the western states, where it was probably introduced from the East within the last quarter of a century. The disease is of American origin and has not appeared in other countries.

Loss from Fire Blight.—The pear and quince suffer more severely from fire blight than does the apple. However, because of the greater value of the apple crop, the financial loss in the case of that fruit is probably greater than in the case of the pear and quince.

Fire blight causes damage in the following ways: (1) by killing the twigs, thus reducing the foliage and fruit-bud formation; (2) by killing the blossoms; (3) by rotting the immature fruit; (4) by killing limbs and entire trees thru blight cankers. It frequently causes a direct loss of 60 to 95 percent of the blossoms on certain susceptible varieties, such as Jonathan. Fortunately other varieties may entirely escape altho planted in alternate rows with the affected varieties.

Susceptibility of Different Varieties.—The most susceptible varieties under Illinois conditions are Jonathan, Transparent, Benoni, Chenango, Willow Twig, and Tolman Sweet; while Grimes, York Imperial, Ben Davis, and Wealthy are only moderately susceptible. Duchess and Winesap are rarely seriously affected by blight. In the southern Illinois orchards, Jonathan and Yellow Transparent suffer very severely from twig blight.

Fig. 17.—Blight canker on apple limb

Symptoms.—The first appearance of blight in the spring is at blossoming time. Blossoms when in full bloom suddenly turn brown and wilt. A closer examination shows the disease extending down the pedicels of the fruit, turning them to a dark brown or black. Later the leaves below the flower cluster may become infected, quickly wilt, and die as a result of extension of the disease into the spurs. At this time twig blight may also be taking place. The leaves on the young twigs wilt and turn brown from the tip downward (Fig. 16). The distance which the disease travels downward is dependent somewhat upon the variety and weather conditions. The leaves are retained on the twigs, giving, together with the blossom blight, a decidedly scorched appearance to the tree.

Blight frequently extends downward from blighted twigs into the main limbs and here causes more or less serious cankers (Fig. 17). In Illinois these cankers rarely cause the death of the branches. The

chief damage is the production of a dead area which serves as a place of entrance for other fungi, such as those causing black rot, blister canker, and bitter rot. Cankers of a serious nature sometimes occur at the base of the trees. These are usually introduced thru water sprouts. They should not be confused with cankers and other injuries as described on page 54. These cankers probably account for so-called "crown rot" in some cases.

The cankers on the limbs usually result from blighted twigs, the remains of which may often be observed near the center of the canker. Limb cankers at first are smooth and slightly sunken, the limits of the canker being defined later in the season by a crack (Fig. 17). Under favorable weather conditions yellowish or dirty gray, sticky drops ooze out of these cankers onto the bark.

On young fruit the disease may appear at any time until the fruit is an inch in diameter. The whole fruit takes on a bruised, watery appearance, and, under conditions favorable to the development of the disease, numerous milky, sticky droplets exude.

Cause.—We owe the discovery of the cause of fire blight to the early investigations of the late Doctor T. J. Burrill, whose work on this disease paved the way for the study of other bacterial plant diseases. He discovered the presence of minute organisms in the exudations from the limbs and fruit attacked by this disease. These organisms proved to be bacteria (Fig. 2), and the particular species causing fire blight of pear, apple, and quince was named *Bacillus amylovorus.*

In spite of the enormous amount of work which has been done on this disease, there are still points in the life history of the organism that are not entirely clear. In general the life cycle is probably as follows: The bacteria live over winter in a few cankers on the apple or more frequently on the pear. These are called "hold-over" cankers. Droplets ooze from these cankers in the spring at about the time the trees blossom. The blossoms probably become blighted by the visits of insects first to the sticky exudate on the hold-over cankers and then to the flowers. The insects are known to carry the germs on their legs and nectar-sucking apparatus. Recent investigations also indicate that bacteria may be carried by wind-borne mist. The bacteria develop in the nectar of the blossoms, enter the tissue, and travel rapidly down the fruit pedicels. The blossoms and leaves are thus blighted and killed. Other sucking insects carry the bacteria to the ends of twigs and here introduce them by means of their punctures. These twigs blight because of the multiplication and spread of bacteria in their tissues and the production of poisonous substances by the bacterial cells. The bacteria travel downward into the limb at the base of the twig and here spread, causing the limb cankers.

Fortunately, development of blight is checked or entirely inhibited by warm, dry weather and maturing of the bark tissues, so that in early summer a sharp line of demarcation is seen between healthy and diseased tissues, and usually no further progress is made. Only in some very favorably located cankers do the bacteria succeed in living over winter. The bacteria develop only in the bark and never go below the cambium line.

Further details of the disease are given under pear blight.

Control.—There is no method of successfully controlling fire blight either on apples or on pears. Methods based on cutting out blighted twigs as they appear are impracticable under Illinois conditions. If it were possible to recognize hold-over cankers and properly treat these, there is little question that the disease could be held in check. The fact that the organism on pear and apple is the same complicates control measures. In a new orchard it is undoubtedly a wise precaution to cut out promptly any twigs seen to be starting to blight, and the prompt treatment of cankers of any nature should be a part of the general orchard practice. When an orchard is set, if there is a choice of two equally good varieties, the one most resistant to blight should be selected.

BLACK ROT

Black rot is found on the apple, pear, and quince, and is also a saprophyte on other plants. It is primarily, however, an apple disease, rarely causing serious damage on other hosts. It has been known in Illinois since 1879, and according to some of the older orchardists was common before that time.

Loss from Black Rot.—The disease is not ordinarily a destructive rot where orchard conditions are such as to keep fruit-eating insects under control. Each year, however, thousands of bushels of apples are lost, many of which are "drops" or "seconds," but nevertheless of considerable value. It is a troublesome storage rot, altho not equalling soft rot in this respect. Limb cankers of a destructive character are also produced.

Distribution.—This disease now has a world-wide distribution. It seems to be most destructive in the eastern portion of the United States, especially in the New England and Middle Atlantic states. The canker form of the disease is most destructive in New York, and is commonly called the "New York apple tree canker."

Susceptibility of Different Varieties.—Varietal susceptibility has not been especially marked in this state, altho Ben Davis is undoubtedly one of the most susceptible varieties. York Imperial, Rome Beauty, and Chenango are also regarded by orchardists as being quite susceptible. Grimes and most early summer varieties show no tend-

ency to rot. In New York, Twenty Ounce is most susceptible to the canker form of the disease. The canker has been noticed in this state most commonly on Ben Davis and Willow Twig.

Symptoms.—On the fruit, the rot is first brown, not black. The flesh below the rotted area is firm and there is no depression as in the case of bitter rot. Even when the fruit is completely rotted the apple remains plump and quite solid. The flesh does not have a disagreeable taste. Frequently there are alternate light and dark bands in the rotted area, giving it a ringed appearance (Plate II, a). The rot most often appears near the blossom end or about a worm hole or other injury. It rarely develops on uninjured fruit except when it starts at the old calyx scar. Fruit suffering from blossom and spray injury frequently becomes rotted, the rot starting in the dead tissues of the spray injury.

As the rot becomes more advanced the tissues become darker, turning first to a deep purplish color (Plate II, b). Over the old rotted area many small black pustules are developed (Plate II, a, b). These may appear shortly after the rot starts or may not appear until after the entire apple is rotted. When a worm hole is the center of infection, the pustules seem to appear earlier than under other conditions. This rot can be distinguished from bitter rot and soft rot by observance of the characteristics listed in Table 2, page 51. The most constant differences are italicized in each case.

It is almost impossible to distinguish between brown rot, caused by *Sclerotinia cinerea,* and black rot until the fruiting bodies are produced. In brown rot these are dry, grayish tufts, while in black rot, pycnidia are formed.

On the leaf, the spots in their later development are often spoken of as "frog-eye" on account of the concentric reddish brown circles about a gray center. These spots are at first of a deep reddish brown or purplish color, and from an eighth to a quarter of an inch in diameter (Plate I, a). The dark color of the spots and the concentric appearance later in the season distinguish them from other leaf spots, such as blotch and rust. Under Illinois conditions the first appearance of black-rot spots on the foliage is late in June or early in July. They are most prominent during August and September, rarely being noticeable before that time. As the lesions become older, the center of the diseased area becomes lighter brown and finally gray, while the edges become irregularly lobed.

Cankers on limbs are usually developed on rather old branches. The following description of a canker is taken from L. R. Hesler's account of the symptoms of this disease.[1]

"In the earlier stages of the formation of a canker, the bark is slightly sunken and reddish brown in color. The diseased area slowly increases in

[1]N. Y. Agr. Exp. Sta. (Cornell) Bul. 379, pp. 62 and 63.

size and darkens, and, altho not conspicuous at a distance, the spot is readily distinguished from healthy tissue on closer examination. Some lesions remain very small, measuring only a few centimeters in their longer diameter; in such cases the canker usually dies out at the end of the year. Where the injury is larger, the diseased spot enlarges from year to year for a distance of a meter or even more.

"The discolored area may extend over a considerable surface; or, regardless of its size, a crevice may appear at the margin, limiting, temporarily at least, the extent of the lesion. Further spread of the pathogene results in the formation of a prominent spot, which soon forms a second line of demarcation between the healthy and the diseased tissue. Repetition of this process from one or more points at the margin occurs, thus producing a lobed appearance; or the spreading may arise from all points about the first marginal crack, so that a series of concentric crevices is developed. The bark remains closely appressed to the wood for at least a year; later the dead bark cracks and falls away, exposing the wood and a callus around the margin of the wound.

"Cankers that begin to form early in the season show numerous fruiting pustules of the pathogene scattered over the central area of the spot. These may not become evident, however, until the second season.

"Large limbs are rarely girdled the first year; the girdling comes about by the enlargement of the canker the following season. Complete encircling results in the death of the parts above the canker, as evidenced by the yellowing and dropping of the leaves and the shriveling of bark and fruit. It is not uncommon in such cases to find the fruit clinging to the twigs for a year or more."

Cause.—Physalospora Cydoniae, a fungous parasite, causes black rot of apple, pear, and quince.

The spores of this fungus are developed in the old mummied fruit in the small, black dots (pycnidia) seen on the rotted surface (Plate II, a, b). These pycnidia are developed on the surface of the bark in the cankers and on dead branches of apple and many other trees and shrubs. They are frequently seen dotting the surface of cankers produced by the fire-blight organism or by the blister-canker fungus. The spores are forced out of the pycnidia in great quantities and may be carried to all parts of the orchard by various agents. They begin to appear as early as the latter part of April and are produced thruout the season. Spores alighting on the fruit, the leaves, and on wounds in the bark germinate under proper weather conditions and produce rot, leaf spot, or canker. The mycelium of the fungus lives over winter in cankers and thus renders a "perfect," or winter-spore, stage unnecessary in the life history of the fungus. The winter-spore stage is known, but it is rare and is of no economic importance.

Control.—In Illinois orchards the amount of black rot has been found to be directly proportional to the number of wormy apples and neglected trees. In those orchards where trees are well pruned and the codling moths and other fruit-eating insects are controlled, the usual spray schedule is sufficient to keep this disease in check.

Where unusual difficulty is experienced with this disease, the following procedure is recommended:

(1) Cut out and burn all dead wood.

(2) Treat all cankered limbs as recommended under treatment of cankers, page 36.

(3) Apply an extra spray of Bordeaux mixture about the middle of July and another the first week in August.

(4) Keep all "drops" carefully picked up and remove promptly from the orchard. It is the common practice in Illinois orchards to pick up for cider stock all fruit not entirely rotted. The completely rotted apples are left under the trees. It would add little to the cost of the operation to pick up all fruit for cider and discard the rotten apples at the mill, or separate them from the more or less sound fruit when picking up and have them hauled out with the cider stock.

(5) When picking up drops, remove from the tree any rotten fruit within reach. While this would not take care of all rotting fruit on the tree, it would include a large percentage of it.

SOFT ROT

Most of the rotting in storage, and especially in the markets, is caused by soft rot. This disease is also called "blue mold," on account of the color of the fruiting bodies; and "bin rot," because of its commonly destructive presence in storage. It is not confined to apples but occurs on many kinds of fruits and vegetables.

Resistance to the disease is dependent upon so many factors that data on varietal susceptibility are unreliable and usually contradictory.

Loss from Soft Rot.—The loss caused by soft rot is especially serious because it occurs after labor and expense have been put into the harvesting, packing, shipping, and storing of the fruit. The actual percentage of loss is hard to determine, since storage men and wholesalers are reluctant to give any information. Inspection of cars of fruit by government inspectors frequently shows as much as 25 percent of diseased fruit. This refers to inspection in transit from cold storage to market. Where scientific cold storage is practiced and good sound fruit prevails there is not a large loss, tho the occasional loss of a few barrels in storage is always anticipated. Where the housewife buys apples in quantity or where the farmer stores a few barrels in the cellar from the small farm orchard, there is often a loss of 50 percent of the fruit. It is a common practice in home storage to sort the fruit several times during the course of a winter, and frequently 10 percent of the fruit is thrown away each time. The retailer who is not equipped with cold-storage facilities is also a heavy loser. Loss from soft rot falls upon the jobber, the retailer,

and the consumer, rather than upon the orchardist, tho there are on record one or two cases of great loss of fruit in the orchard by this fungus.[1]

Symptoms.—Soft rot can usually be distinguished in its early stages by the light color and soft, watery texture of the rotted areas. The taste is characteristic, being disagreeably moldy. The odor is perhaps the most reliable method of detecting the rot in a barrel or bin. A few half-rotted apples can be detected even when they are in the bottom of a barrel, and the characteristic strong, moldy odor, and frequently the taste, cling to apples which have been kept in the neighborhood of rotted ones.

The rot when started advances rapidly, especially when temperature conditions are favorable. The whole fruit may be rotted within two weeks after infection. The rotted area does not become sunken; it is usually yellow or light brown in color, very soft in texture, and not inclined to wrinkle (see Table 2, page 51). In a barrel placed where the humidity is relatively high, the surface of the diseased portion of the fruit becomes studded with the characteristic grayish blue cushions of the fruiting bodies. Frequently these do not appear on the apple at all, this being especially true where the air is not humid.

Cause.—Soft rot is usually caused by the fungus *Penicillium expansum.* Some other species of the genus Penicillium occasionally cause a very similar rot. *Penicillium expansum* and related species grow on all sorts of decaying material and upon numerous fruits. The spores are produced in enormous numbers and are scattered broadcast. They are very resistant and consequently may be regarded as always present and able to infect if conditions are favorable. Fortunately this fungus is only weakly parasitic. It is also primarily a disease of ripe fruit, rarely attacking green fruits.

The spores of the soft-rot organism fall upon wounded surfaces, immediately germinate, and soon develop a branched mycelium in the tissues of the apple, rotting the connecting substance of the apple cells and causing them to become dissociated. This results in the characteristic soft texture of the diseased tissues. After partly or entirely rotting the fruit, if placed under proper moisture conditions, the fungus develops bluish gray tufts of fruiting bodies on the surface. These consist of numerous broom-like branches upon which thousands of spores are produced. These spores are very light and are readily carried by drafts of air in all directions, infecting other apples. The spores do not become wet when dropped in water but float like dust on the surface. They may be blown into the air from

[1]See Brooks, Chas., Fisher, D. F., and Cooley, J. S. Phytopath., 4 (1914), 403. "During the past summer a particularly virulent strain of this fungus has been the cause of serious damage to immature fruit in the Northwest, in some cases destroying more than 10 percent of the crop while still on the trees."

the surface of a drop of water. When fruit is in close contact, as in barrels, the mycelium may pass directly from one fruit to another provided there is a bruised surface on the second fruit. Frequently soft-rotted apples are mashed in the barrel when it is handled, and portions of the rotted fruit are pushed into other parts, infecting the apples thru wounded surfaces. Sound fruit may remain in contact and partly surrounded by entirely decayed apples and not become infected, altho usually it is rendered worthless by the moldly taste imparted to it.

Control.—The life history of the fungus indicates the best method of reducing losses from this disease. There is no way of avoiding the possibility of infection since the living spores of this fungus are omnipresent. The fact that the fungus cannot gain entrance to sound fruit is an important point in control measures. Every effort should be made to avoid injuring the fruit, so that it may present to the spores an unassailable front.

The fungus may gain a foothold thru lesions produced by other fungi, thru insect injuries, or thru wounds resulting from the handling of the fruit by pickers, graders, packers, and market men. The fruit should be kept as free as possible from insect and fungus attack in the orchard, and in packing, all diseased fruit should be discarded or packed in separate barrels. Worm holes and scab or blotch spots furnish places for infection. The finger-nail scratch of the picker or packer, or scratches from twigs, rough places on crates, barrels, mechanical graders, projecting nails, etc., frequently cause wounds sufficient to permit the entrance of the fungus.

Next to care in picking and packing, the important factor in controlling the disease is keeping the temperature of the fruit as low as possible. When it is to be stored for long periods, refrigeration is necessary. The purpose of cold storage or refrigeration is twofold: to retain the texture and flavor of the apple in as nearly natural condition as possible, and to prevent decay.

Since most fruit rots are caused by fungi, it is of interest to know the effect of decreased temperatures upon the development and relative growth of these organisms. Actual experiments have shown that Penicillium and other rot-producing fungi are able to develop at temperatures as low as can be obtained without injuring the fruit. But the growth is very slow at low temperatures and is almost entirely inhibited at 32 degrees to 35 degrees Fahrenheit. It has been found also that the development is much slower if the fruit is placed in cold storage immediately after picking. *Penicillium expansum* when allowed to develop at normal temperatures for a week rots fairly rapidly even when placed at a temperature of 35 degrees Fahrenheit; while, if placed immediately in cold storage, actual rotting may be delayed for several months. It is therefore important to ship apples to the point of storage in iced cars when possible, unless the outside

TABLE 2.—COMPARISON OF BLACK, SOFT, AND BITTER ROTS

BLACK ROT	BITTER ROT	SOFT ROT
(1) *Rot spots not concave*	*Rot spots concave* (saucer shaped)	Rot spots not concave
(2) *Texture of rotted area rather firm*	Texture of rotted area firm	*Texture of rotted area very soft, "mushy"*
(3) Rot spots brown turning to black	Rot spots dark brown	Rot spots *light brown to yellow*
(4) Rot spots usually arising from wound, insect puncture, or from blossom end	*Rot spots scattered over the surface, usually not arising from an insect puncture*	Rot spots usually single
(5) *Pustules black dots*	*Pustules pink*	*Pustules rarely developed in orchard;* when developed gray-blue in color

temperature is quite low. Efforts should be made also to have the temperature as low as possible during picking, packing, and hauling, since even in cold storage the center of the barrel may remain warm for three to five days.

After the fruit is in storage, it should not be disturbed more than is necessary. In cellar and bin storage, the same care should be exercised in handling the fruit. Where practical, frequent sorting should be practiced, to remove diseased fruit before the production of spore bodies. Bins and cellar walls should be thoroly cleaned and disinfected. Since cold storage alone cannot entirely prevent the development of soft rot, careful handling of fruit before and after picking cannot be overemphasized.

PINK ROT

Primarily a storage rot, pink rot rarely causes loss in the orchard. Where apples have been attacked by scab and care has not been taken to place them at once in storage after harvesting, there is usually considerable loss from pink rot, but little loss is experienced if proper care has been taken.

This rot is widely distributed, being reported as a serious disease in most of the apple-growing regions of the globe.

Symptoms.—Pink rot is characterized by the early appearance of a pink, fluffy mass on the surface of the scab lesion (Fig. 20). Before this appears, however, a close observation of scab spots shows a brown, rotted zone about the superficial scab area. The scab lesion becomes sunken because of the rotting of the flesh beneath it. The rotted areas do not extend rapidly and are often checked in their growth just beyond the scab spots. However, even under these conditions, the rot is sufficient to ruin the fruit.

Cause.—The fungus causing pink rot is *Cephalothecium roseum.* This fungus is a saprophyte which ordinarily lives on all kinds of decaying vegetable matter. It is much like blue mold, or soft rot, in

this respect and in the almost omnipresence of the spores. It cannot gain entrance to the sound apple, but when the spores light upon scab lesions or other wounds they germinate, if moisture conditions are favorable, and after living for a while on the dead tissue rot the surrounding cells.

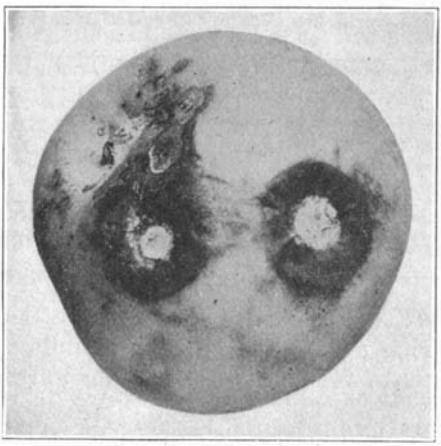

Fig. 20[1].—Pink rot following scab. The dark areas surrounding the white central spot show the beginning of active rotting due to the fungus

It is only under exceptionally favorable conditions that rotting is brought about by this fungus. The habit of some orchardists of piling the fruit before packing especially favors the development of this fungus, as the apples "sweat" and thus furnish the humid conditions necessary for the initial development of pink rot. The very noticeable association of pink rot with scab may be attributed to two factors: the ruptured condition of the skin at scab lesions, and the presence of an exceptional amount of moisture in scab spots. If scabby apples are placed in a humid atmosphere, it is noticeable that scab spots absorb and hold the moisture to a remarkable extent. Pink rot frequently appears on fruit that was apparently sound when put in storage or on fruit after it is brought out of storage. In both cases, this is because the spores of the fungus were abundantly present, and the conditions were such as to favor their development.

Control.—The chief method of control is to reduce scab by careful spraying. Pink rot is not to be feared where scab is absent. Piling fruit in the orchard previous to packing cannot be too strongly condemned, not only because it favors the development of pink rot, but also from the standpoint of general sanitation. Special care should be taken with scabby fruit, storing it at as low a temperature as possible and taking precautions to prevent sweating and excessive humidity.

SOOTY SMUDGE[2] AND FLYSPECK

In poorly pruned orchards located on low ground, a cloudy or smoky appearance is produced on the fruit during damp seasons which may result in materially reducing its market value. This disease,

[1]Figs. 18 and 19 withdrawn.

[2]The common name, sooty blotch, as applied to this disease, has so often led to confusion between it and true blotch that it is thought best to take this occasion to introduce the name sooty smudge. It is regarded as a more descriptive and limited term than "cloud."

sooty smudge, is also commonly called sooty blotch or "cloud" on apples and pears.

Accompanying sooty smudge there may be a disease evidenced by minute black dots resembling to a remarkable degree ordinary flyspecks. The damage done by this malady is not extensive, as the

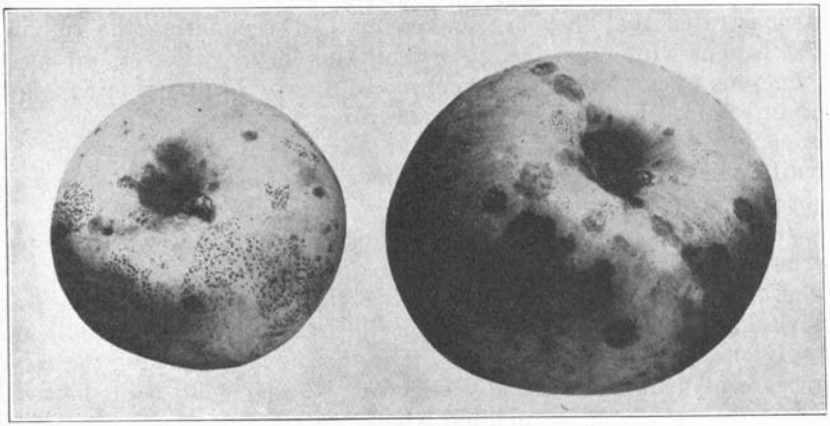

FIG. 21.—SOOTY SMUDGE AND FLYSPECK

growth is entirely superficial, but the market value of the fruit is reduced, particularly in the case of green or yellow varieties. The disease usually appears late in the season and only during wet or very cloudy summers, except occasionally on low ground.

Sooty smudge is especially severe in the southern Mississippi valley apple-growing region and in some eastern sections of the country.

Symptoms.—Sooty smudge should be clearly distinguished from blotch (see page 21). In the case of smudge there are black, smoky, or sooty spots on the surface of the apple (Fig. 21). These are entirely superficial and do not cause either a sinking or an elevation of the surface of the apple. They are dull in color, while the true blotch is slick and shiny. Spots of sooty smudge are indefinite in outline and do not show the root-like extension characteristic of the spreading type of the true blotch (compare Fig. 21 and Fig. 5).

The flyspeck disease which often accompanies sooty smudge is best described by its name (Fig. 21).

Cause.—There is some confusion regarding the cause of sooty smudge and flyspeck. The two diseases were at one time believed to be caused by a single species. The recent investigations of Doctor A. S. Colby[1] indicate that the fungus causing sooty smudge is entirely distinct from the one causing flyspeck. He has named the sooty-smudge fungus *Gloeodes pomigena.* The flyspeck fungus re-

[1]Doctor's Thesis, University of Illinois, 1919.

tains the name *Leptothyrium Pomi,* which has been used by many authors to include both fungi.

The sooty-smudge fungus spreads over the surface of the apple by means of a much branched and anastomosing mycelium. Certain cells of this mycelium become thick-walled and separate from the mycelial mass. These cells are called *clamydospores,* and Colby has demonstrated that they are important in disseminating the fungus. The fungus winters on the fallen fruit and on the twigs. It produces numerous pycnidia but the pycnospores appear to play a minor part in infection. Little is known concerning the time and manner of infection, but the relatively late appearance of the disease on the fruit indicates a late-spring or summer infection. The fungus does not spread in storage.

Few facts concerning the life history of the flyspeck fungus are known.

Control.—Where these diseases are causing serious trouble, it is advisable, in addition to following the regular spray schedule, to apply one or two sprays during July and August. Opening the trees by careful pruning is usually effective in controlling both diseases. Orchards should not be planted where the air drainage is poor.

ROOT DISEASES OF THE APPLE[1]

Probably the most serious loss in Illinois orchards results from dying of entire trees between the time of planting and maturity, the maximum death period being between the fifth and fifteenth year. There are few orchards in the state where there has not been a loss of at least one percent of the trees from root trouble, and in many orchards from ten to fifteen trees out of every hundred are either missing or have been replanted. Root diseases are especially serious because the annual production of fruit is of course reduced in proportion to the number of dead trees.

Symptoms.—The symptoms of root rot or root injury, whatever the cause, are usually the same, and for this reason the orchardist is inclined to regard them as due to one causal agent. The first indication of any disease or injury to roots or crown of the tree is the "off color" appearance of the foliage. As one looks across an orchard, these trees appear lighter in color than their neighbors. Later in the season the leaves are decidedly lighter in color, often taking on a yellowish green shade. The following year the leaves frequently fail to develop to their normal size and the yellow tint is more decided. If the tree survives this season, it is often killed during the following year. Sometimes the symptoms described for the second year may continue for three or four years. Often during the second year there

[1]Root diseases as here classified include all those below the ground line. In some cases the disease may show also on the bole.

is a decided increase in the amount of fruit on affected trees tho this fruit is usually smaller at the end of the season than that of the normal trees.

It often happens that only one side of the tree or a single limb shows the symptoms here described. It is generally the rule that the above-ground symptoms do not become evident until the root system has been seriously affected. This means that the causal agent has been acting for from one to several years.

The number of years which the tree may live after the first appearance of symptoms on the foliage depends upon the nature of the disease, the condition or vigor of the tree, the soil and weather conditions, and other factors as indicated below.

Causes.—The agents and conditions which bring about root troubles may be classified roughly as follows:

1. Soil Conditions
   - (1) Poor physical character
   - (2) Lack of proper drainage
2. Climatic Conditions
   - (1) Winter injury
   - (2) Sun scald
   - (3) Drouth
   - (4) Excessive moisture
3. Animal Injuries
   - (1) Rodents: Mice, rabbits, gophers, moles
   - (2) Insects: Root lice (woolly aphids), borers
4. Fungous and Bacterial Parasites
   - (1) Crown gall
   - (2) Fire blight
   - (3) Xylaria root rot
   - (4) Armillaria root rot
   - (5) Saprophytic wood-rotting fungi
5. Physiological Conditions
   - (1) Lack of essential nutrients
   - (2) Excessive nutrients
   - (3) Uncongeniality of stock and scion
6. Mechanical Injury

It is usually a combination of several of these factors which brings about the final death of the tree. For example, Xylaria root rot can gain entrance only thru wounds. These wounds may be produced by insects or workmen. Again the lack of a good physical texture of the soil may bring about winter injury or may account for the failure of the graft and scion to function normally. Woolly aphids are more abundant and destructive in some types of soils than others. In some cases trees suffering from crown gall may be attacked by borers and woolly aphids, or send out sprouts which may be blighted, thus producing collar rot. Mice may almost girdle a tree below the surface of the ground, and the numerous small roots formed above the gnawed area may save the tree; but these roots in turn may be attacked by

woolly aphids, or severe drouths may prevent them from obtaining sufficient moisture to keep the tree alive during the season.

In the discussion of root diseases which follows, these various contributing factors must be kept in mind. It is necessary also to remember that little can be told by the external symptoms of the tree; the root system must be examined.

CROWN GALL

Loss from Crown Gall.—Crown gall, also known as "crown knot," "root knot," and "hairy root," causes most serious loss in nurseries, not only of apple trees but of many other fruit trees and bush fruits. The disease is not confined to young trees, however, but is very commonly found in old orchards. Frequently a few trees are seen which are small and less thrifty than the rest. These often live many years but rarely produce their quota of fruit.

On account of the nature of the disease, it is difficult to estimate the losses from crown gall. Losses may result from the following conditions: (1) The trees may be killed in the nursery; (2) they may die in the orchard after a short period of growth; (3) they may live many years but remain dwarfed and unproductive; and (4) fungi and insects may gain entrance at the galls and cause the death of the tree.

The roots and crown of the tree are the points usually attacked. In nurseries, the graft union is commonly the point of attack probably because of the presence of exposed surfaces and tender tissues. Galls may appear also on the limbs, but such are rarely observed.

Distribution.—Crown gall is found to some extent wherever apple trees are grown. It is regarded as more destructive in the Rocky mountain region and on the Pacific slope than in the eastern and central portions of the United States. It is also reported as destructive in the southern states.

Host Plants.—The list of host plants for crown gall is too extensive to give in full. It is found on such widely different hosts as the rose, grape, sugar beet, daisy, willow, hop, and poplar. Among fruit trees, it is common on apple, peach, pear, apricot, plum, cherry, quince, and almond. On bush fruits, it is most commonly found on raspberry and blackberry.

Susceptibility of Different Varieties.—There are few accurate data concerning the relative susceptibility of apple varieties. None are known to be immune. Early Harvest, Wealthy, Ben Davis, Grimes, Gano, and Rome Beauty are said to be quite susceptible.

Symptoms.—Two distinct forms of the disease are recognized: galls, and hairy roots. The galls are in general somewhat globose, abnormal outgrowths of the woody tissues and vary in size according

to age and conditions of growth. Mature galls are frequently several inches in diameter (Fig. 22), while the younger ones may be no larger than a pea. The surface is usually rough and warty, but when the gall is young it may be quite smooth. The smaller galls are frequently quite soft and light in color, while older ones are dark and often as hard as the wood of the tree.

Hairy root was at one time considered as distinct from crown gall but it is now known to be caused by the same organism. Fibrous roots in large numbers are produced at the crown and along the tap root. This gives a bushy, hairy appearance quite characteristic when well developed. Combinations of hairy root and crown gall and all gradations between the two occur.

Fig. 22.—Crown gall on apple

Frequently abnormal growths appear which are not caused by the crown-gall organism but which may be mistaken for the gall or the hairy-root type of the disease. A callus is often formed at the graft union which in every respect resembles a small gall. Injuries about the crown frequently start a callus quite similar to the true galls. Abnormal swellings of the tissues at the graft union frequently occur and resemble the girdling type of the gall. Further, when the young trees are grown under very favorable conditions, numerous small roots are produced which may easily be mistaken for the hairy-root type of the disease.

Cause.—Crown gall is caused by a bacterium, *Bacterium tumefaciens.* This is a very minute rod-shaped organism which lives in soil as well as in the plant tumors. It is probably rather generally distributed in cultivated soils, since there are so many hosts in which it is able to live. There is no doubt that some soils become more heavily infested than others.

Insects and the tools of workmen may carry the pathogene from tree to tree, especially in the nursery rows. It is thought also that it is carried thru the soil by water, infecting the tree thru open wounds. It has been proved that cutting into active galls and then using the same knife to cut healthy trees transfers the germs and produces new galls. The bacteria when rubbed on cut surfaces also produce the disease.

After the bacteria enter, they multiply rapidly and stimulate the dividing cells of the host plant to greater and abnormal activity, giving rise to tumors on the surface. They are also carried up and down the stem in channels which are not evident externally, producing new galls at a distance from the primary infection.

The organism causing crown gall on other plants is undoubtedly the same as that which causes this disease on the apple, and it has been shown repeatedly that the bacteria from daisies and beets may be transferred to apples and pears.

To summarize, the bacteria which cause the disease are present in the soil, and in old tumors not only of apple but of many other plants. These bacteria gain entrance to the host plant thru wounds and, by abnormal stimulation, produce either the gall or the hairy-root type of the disease.

Control.—There is no satisfactory method of completely controlling this disease. Cutting off the tumors is not reliable, since internal strands are usually present and cannot be removed.

Sanitary methods in the nursery are essential. Care should be taken to avoid unnecessary wounding of stems and roots. Instruments used in grafting and pruning should be constantly sterilized by dipping in mercuric chlorid or copper sulfate solutions. The graft union should be carefully wrapped. If a large number of diseased plants are found in any part of the nursery, this part should be given over to field crops for several years before again being used for nursery stock.

While there is reliable evidence that stock suffering from crown gall may be planted and the trees remain as thrifty and productive as perfectly healthy trees, the orchardist cannot take a chance with them when the cost of bringing an orchard into bearing is considered. Only unquestionably clean stock should be accepted by the orchardist. Rigid insistance on this point will result in making the nurserymen take greater pains to produce clean stock and discard all suspicious trees when shipping.

BLACK ROOT ROT

Recent observations in southern Illinois have shown that many trees in this region are suffering from a type of root rot different from the root rots ordinarily found in Illinois orchards. The extent and destructiveness of this disease is imperfectly known, and the information here given is to aid the grower in identifying the disease so that he may make further observations on its distribution and relative importance. While it is a disease described but comparatively recently, there is evidence that it has a fairly wide distribution. It has been reported from most of the apple-growing states east of the Mississippi.

The severity of the disease in southeastern apple orchards may be indicated by the following from Virginia: "A special survey has been made for black root rot of apple caused by Xylaria. It has been found thruout the apple-producing sections in the state and, in the opinion of some growers, is more destructive than all other diseases of the apple combined. I have found tree losses running as high as 25 percent in twenty-year-old orchards. A 5 percent loss in bearing orchards would certainly be a conservative estimate for the general run of infested orchards and in some districts fully 50 percent of the orchards are infested."[1]

Symptoms.—The surest method of recognizing this disease is thru examination of the root system. On the surface of the bark of the roots, when these are not entirely rotted, a black incrustation may be observed. This characteristic black appearance of the roots gives the name to the disease. When the wood of a diseased root is cut across, alternate light and dark brown circles are seen. The wood of well-rotted roots is quite brittle, and the roots frequently break off near the trunk when attempts are made to uproot the tree.

Fig. 23.—Fruiting body of fungus causing Xylaria root rot

The finger-like fruiting bodies of this fungus, in the soil at the base of the tree, easily distinguish it from other root troubles (Fig. 23). These bodies appear in the early summer and for some time are white on the surface with a black interior. Later in the season they become black thruout, except at the tips, where they remain white until fall. They are to be found all winter and in the early spring. These fruiting bodies are not always present, and in some parts of the country they rarely appear. This makes it necessary to examine the root systems of suspicious looking trees.

Superficially, the effect upon the tree is not different from that of a large number of other root and crown diseases. Slight yellowing of the foliage is the first indication of root trouble. This may last for a year or more. Later the leaves become decidedly smaller, frequently dropping off before the end of the year. During the follow-

[1]F. D. Fromme. Plant Disease Bulletin, 1 (1917), 73.

ing winter the death of the tree usually takes place. Frequently parts of the tree show distress signs, and one side may die before the other. The diseased tree often leans towards the side most severely attacked.

Cause.—Two species of the fungus genus Xylaria have been found causing the black root rot here described. The exact relationship of these species has not been fully determined. It appears that *Xylaria digitata* is the most common and destructive species, and the only one which has been observed in Illinois.[1]

These fungi live on a number of forest and fruit trees and are usually found growing saprophytically in the roots of old tree stumps about which the finger-like sporophores of the fungus appear in clusters (Fig. 23). On these sporophores are borne millions of minute white conidia which give them a white, mealy appearance during the spring and early summer. These conidia are probably carried by wind, water, and insects thruout the orchard. They can germinate in a short time if moisture is present, and since the fungus is saprophytic it can live on decayed roots and vegetable matter in the soil. A mycelium is thus developed which spreads thruout the soil. If it should come in contact with the apple roots it could gain an entrance thru wounds or rotted areas and thus start its parasitic existence, causing the root to decay as it grew into the tissue.

It has been stated that the finger-like sporophores are developed at the base of the trees. They produce ascospores in perethecia which are embedded in the tissue of the sporophores. These ascospores are discharged and can germinate in the same manner as the conidia. It is probable, however, that the ascospores are not so important in spreading the disease, for the mycelium can easily spread thruout the soil, either from the infected roots or from germinating conidia. It is therefore not necessary for either the conidia or the ascospores to come in direct contact with the wounded surfaces of the roots.

The full details of the manner of infection have not been worked out, and the foregoing is given as the probable method of distribution and infection on the basis of our knowledge of other fungi of like nature. It should be remembered that this disease is found on forest trees and may thus get a start in the orchard.

Control.—There are no known methods of control for this disease. General sanitation, removal and destruction of old stumps, and care to avoid wounding roots in cultivation, are the most important precautionary measures. It has been found that the disease is worse on recently cleared land than on land which has been in field crops for a number of years. This is to be expected since forest trees are subject to the disease. For this and other reasons it is often unwise to put an orchard on recently cleared land or on fields where the stumps have not been removed at least a year or so previous to planting.

[1]Letter from F. D. Fromme. May 25, 1919.

ARMILLARIA ROOT ROT

Serious root rotting sometimes occurs on land which has been in forest previous to being planted in apple orchards. The "mushroom" root rot, as it is commonly called in this state, is perhaps most frequently responsible for this condition. In prairie lands the disease is rarely observed and never causes serious damage. Root troubles in such regions are in the majority of cases ascribable to other causes (see page 55).

The amount of damage directly due to Armillaria root rot in Illinois is probably not great and is decreasing as virgin forest land becomes less commonly planted to apples.

In addition to causing root rot of apples, this disease is common on a large number of other fruit trees and bushes as well as on forest trees and ornamental shrubs. It causes more trouble on the Pacific coast than elsewhere. It is common on grapes and was first described in 1887 as occurring on the roots of this fruit near St. Louis. The disease is also common and destructive in Europe.

Symptoms.—To the average orchard man, the first evidence of this root rot is a yellowing of foliage and a decrease in the size of leaves. This is not, however, characteristic of this disease alone, since it is a common phenomenon in the case of practically all root troubles, whether they are due to this or to mouse injury, crown gall, or Xylaria root rot.

When the yellowing is noticed, however, an examination of the base of the tree and the larger roots will show characteristic indications of the disease (Fig. 24). The bark is rotted and dead over the entire crown, extending down around the main roots. The bark is not usually slimy, as in the case of death from winter injury or other causes, but somewhat dry and brittle. When the bark is removed there are numerous fine white threads between the wood and the bark. Accompanying these are larger tough black strands, about one-sixteenth inch in diameter, which grow thru the bark, into the wood, and between the bark and the wood. They also extend out into the soil for some distance. These strands have been called "shoe strings" because of their size and color, and on this account the disease has frequently been called the "shoe-string rot." "Toadstools" develop in the fall from the strands and appear in clusters near the base of the tree.

Cause.—The disease is caused by a fungus, *Armillaria mellea.* It is a mushroom or "toadstool" fungus and lives commonly on old, decaying wood. It is not necessarily a parasite but occurs in the woods and on recently cleared land on rotting stumps and roots.

The large shoe-string-like strands probably enter the root or crown of the tree thru wounds of various sorts. The white mycelium al-

ready described grows out from the strands and spreads fan-like between the bark and the wood, killing the tissues as it advances. The strands or rhizomorphs also continue to develop beneath the bark. The rhizomorphs grow out some distance into the root, and from these the sporophores arise. These sporophores, or "mushrooms," are the

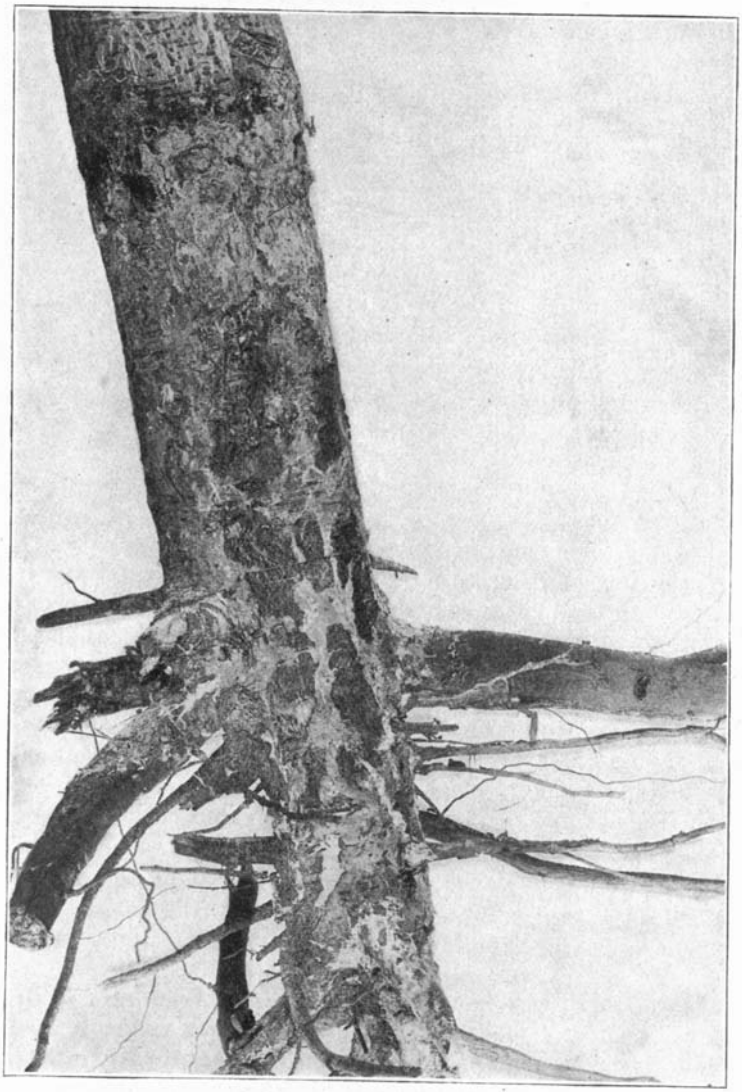

FIG. 24.—"MUSHROOM" ROOT ROT OF APPLE

Note white fungus growth on the root surface and mycelial strands extending along the lateral root to the right

fruiting part of the fungus, producing enormous numbers of spores on the "gills" beneath the cap. The spores drop to the soil or are carried some distance by the wind. They germinate and the mycelium developed from their germ tubes feeds upon the humus in the soil or enters the wounds in the roots of the tree and starts the rotting.

The sporophores, or "toadstools," are from two to seven inches in height, with a tan cap two to five inches across. The top of the cap is light tan at first, but becomes darker with age. It is slick and shiny in appearance, resembling a caramel icing. The gills on the underside of the cap are white. On the stem, which is also white, there is usually a ring about two-thirds of the way between the root and the cap. This is called the annulus. The rhizomorphs together with the striking sporophores are the characters by which the disease may be identified.

Control.—Prevention of the disease consists first in the proper selection of a site. Recently cleared land should be avoided in so far as possible. Old orchard sites too are open to suspicion unless the history of the orchard shows no indication of serious loss from root rot.

When the disease occurs in an orchard, the following procedure has been recommended. Those trees which appear to be diseased should be examined. If the rhizomorphs previously described are found, the tree, together with all the larger roots, should be removed. If for any reason the tree is left, a trench two feet deep should be dug around it near the ends of the roots.

Satisfactory results have been obtained in Oregon by "airing" the roots of diseased trees. The dirt is carefully cleaned away from the crown of the tree so as to expose all the larger roots. The dead and seriously affected roots are removed, the diseased areas on the other roots carefully cleaned out, and the wounds disinfected as in the treatment of cankers (see page 36). The roots are then left exposed thruout the summer, and in the fall the wounds are painted and the dirt filled in around the tree.

Several other toadstool root rots, similar in nature to the Armillaria rot are known.

PHYSIOLOGICAL DISEASES OF THE APPLE

There are a number of diseased conditions in apples, as well as other fruits, that are not due to parasitic fungi and bacteria, nor to insects, but to climatic conditions, abnormal water or gas relations, or nutritive disturbances. These are spoken of as physiological diseases and include water core, bitter pit, scald, drouth injury, sun scald, and spray injury; also injuries from hail, frost (including winter injury), floods, lightning, and winds.

An extensive discussion of all such troubles, is beyond the scope of this publication, but there are a few physiological diseases, especially of the fruit, which from the nature of the injury are likely to be confused with the parasitic diseases. A few of these will be described.

JONATHAN SPOT

The disease here described as Jonathan spot is intended to include only the superficial spotting caused by physiological disturbances. Several diseases more or less alike in superficial appearance have been described by various writers under the term Jonathan spot, or Jonathan spot rot. There is also a tendency to confuse Stippen, or Baldwin spot, with Jonathan spot. The spot here described is always superficial and cannot be detected in the flesh of the apple.

Jonathan spot is very prevalent during some seasons, while in other years it is very difficult to find a single specimen. Altho it does not primarily injure the fruit, it detracts from its appearance and reduces its market value. Furthermore, the spots serve as a place of entrance for more serious rot fungi, especially Alternaria (see page 72).

The disease is found both in the orchard and in storage, but usually appears as a storage rather than as an orchard trouble. Spotting often takes place in transit, since the facilities for complete cooling, aeration, etc., are not always satisfactory. This is especially true of apples shipped from western orchards to eastern markets.

Susceptibility of Different Varieties.—This disease is called Jonathan spot because it is more frequently found on the Jonathan apple, but it is by no means confined to this variety. A number of varieties such as Wealthy, York Imperial, Esopus, and Grimes, develop this trouble in storage. Under Illinois conditions it is far more prevalent on Jonathan, however, than on any other variety and rarely occurs in the orchard on other varieties. A number of western varieties develop this disease in transit.

Symptoms.—The disease does not appear until the fruit is nearly mature; it is primarily a storage trouble. The lesions are first seen as very small, discolored areas, usually near the blossom end and quite uniformly distributed. On the surface of the apples there are normally many small dots called lenticels. These are usually the centers of the diseased spots. Later the lesions become slightly larger but are rarely over one-eighth of an inch in diameter (Plate II, f). As they increase in size they become darker in color and are slightly saucer-shaped.

The trouble is confined to the first few outer layers of cells and, as pointed out by Brooks of the United States Department of Agriculture, this disease can be distinguished from most other spot rots

by the fact that it is impossible to peel the apple thin enough to find any dead cells in the unpeeled portion below the spots.

Usually there is a fungus (Alternaria) that gains entrance to these dead areas, and thru its growth the characteristic appearance is changed, the spots becoming larger, darker, and deeper. This fungus is so frequently found associated with the disease that it often has been mistaken for the primary cause of the rotting (see page 72).

Cause.—To understand the cause of Jonathan spot it is necessary to explain some of the physiological activities of the apple. Such fruits as the apple are made up of living cells which undergo certain chemical changes even when in storage. These changes are accompanied by a process of breathing or respiration similar to that of animals. They take in the gas, oxygen, and give off another gas, carbon dioxid. The exchange of gases takes place thru the lenticels, about which the diseased area is almost always found. It has been found that interference with the exchange of gases, or respiration, thru any cause results in the destruction of some of the color-bearing outer layers of cells. Under some conditions this results in a type of injury known as scald, while under other conditions spotting, such as Jonathan spot, results. This spotting can be caused artificially in storage by increasing the temperature or by reducing air circulation and increasing the humidity. Any factor that prevents proper aeration may cause the appearance of the disease.

Control.—There is no way to control Jonathan spot in the orchard, since the disease is dependent upon weather conditions. Spraying, however, will prevent secondary infection by various fungi.

In transit and storage it is possible to control aeration, temperature, and humidity to a certain extent; and, in general, reducing temperature and humidity and increasing aeration reduces the chance of spotting. Every effort should be made to give proper circulation of air in storage. The temperature, both in transit and in storage, should be maintained as low as possible. Even under the best conditions it is frequently impossible to prevent this disease entirely.

BITTER PIT

Altho bitter pit, or "Stippen," has been known for several decades in America and for a half century or more in Europe, it has not been clearly differentiated from other physiological diseases, nor has it received the attention its importance warrants. The disease is known as "Baldwin spot" in the eastern section of the country, while in this state it has frequently been called "dry rot" and "hollow core," according to the nature of the symptoms.

Distribution.—Bitter pit seems to be very widely distributed, appearing in all countries where apples are grown. It seems to be more

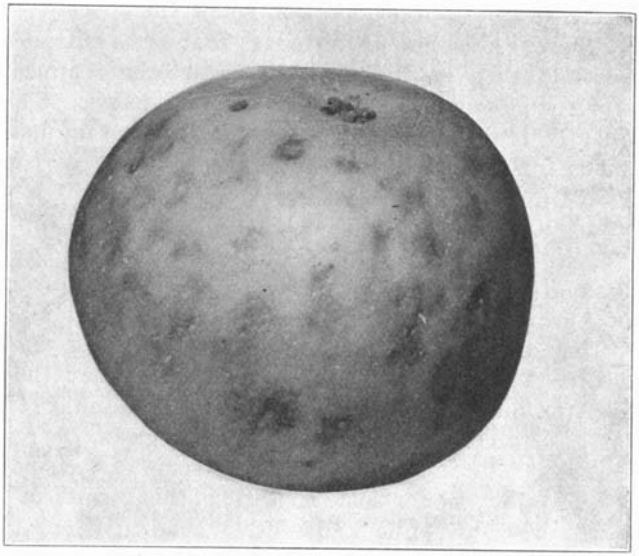

FIG. 25.—BITTER PIT, OR STIPPEN

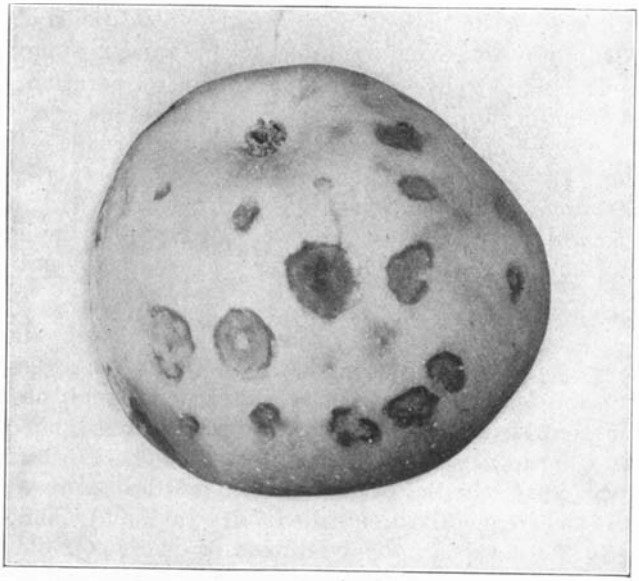

FIG. 26.—STIPPEN FOLLOWED BY ALTERNARIA ROT

serious in regions where weather conditions prevail which differ from those of the regions where the apple is native. However, some varieties suffer in any locality during years of abnormal weather conditions. Australia has had more of this trouble than any other apple-growing country. The same climatic conditions which favor Jonathan spot in the orchard cause Ingram to show the bitter pit.

Susceptibility of Different Varieties.—There are no known varieties immune to the disease, but where Baldwins are grown this variety is notoriously susceptible. In Illinois, Ingrams suffer most severely.

Symptoms.—This disease appears on fruit when it is nearing maturity. At this time sunken areas appear over the surface of the fruit, usually being more numerous at the blossom end (Fig. 25). The skin above the spot at first is not dead or brown in color but is usually darker than the surrounding portion. In the case of green varieties it is darker green, while in red varieties it is of a deeper shade of red. This clearly distinguishes the disease from Jonathan spot. Below these sunken areas there is always a lens-shaped layer of dead, light brown, dry, corky tissue which usually extends for a quarter of an inch into the flesh. This characteristic also differs from Jonathan spot, the diseased area of which is strictly superficial. Many spots occur in the flesh of the apple which show no connection with the surface lesions. The fruit affected with this disease frequently rots owing to the attack of the Alternaria fungus (Fig. 26).

Cause.—While it is well established that bitter pit is not caused by plant parasites or insect attacks, there is considerable difference of opinion as to the factors which bring it about. It seems fairly definitely established that an abnormal water relation is the chief factor. Where there is an even distribution of water during the season, with no long drouths or excessive rainy periods, there seems to be little tendency toward bitter pit. It has been noticed that where the fruit is unevenly distributed over the tree or where unusually large fruit is produced, as, for example, on young trees having only a few apples, there is more bitter pit. In irrigated regions, the disease is most apt to develop when water is unevenly applied.

Control.—In Illinois orchards, there are few recommendations which can be made for the control of this disease, since the conditions under which apples are grown vary so much in different parts of the state and from season to season. Furthermore, there has been no serious loss from bitter pit in Illinois. In general, it is recommended (1) that orchards be planted on soil naturally well drained, (2) that drainage be practiced in established orchards, (3) that injudicious pruning and thinning be avoided, and (4) that efforts be made to secure an even stand of apples on all trees.

SCALD

When apples are taken out of storage and left exposed for a few days, it frequently happens that the entire surface or large areas become soft and take on a brown appearance, thus reducing the selling quality and frequently the keeping quality of the apple. This condition, known as scald, occurs commonly in storage and is the cause of great loss in transit.

Unlike Jonathan spot, scald is found on a large number of varieties, altho, according to some growers, it is more serious on tender-skinned than on tough-skinned apples.

Symptoms.—In its early stages, scald resembles Jonathan spot, altho the diseased area is usually lighter in color. Soon, however, the lesions become much larger and the line of demarcation between healthy and diseased areas is not sharp. When scald is serious the entire fruit may become a light brown color. Usually only the superficial layers of cells are involved and the discoloration does not extend into the fruit. In some cases the browning extends into the flesh.

Cause.—There is a wide difference of opinion among fruit men as to the conditions which bring about scald. Some claim that it is caused by changes in temperature during storage; others that too sudden cooling is responsible; still others attribute it to the change from the cold storage to the outside air. There is no doubt that there is frequently a rather sudden appearance of the disease after removal of the fruit from cold storage.

Apple scald is probably caused by "abnormal respiratory conditions resulting from poor aeration" as pointed out by Brooks and others. The conditions which bring it about are those favorable to Jonathan spot.[1]

Control.—The same precautions for proper aeration and temperature control recommended under Jonathan spot are to be taken in attempting to reduce loss from scald.

CRACKING OF FRUIT

In the summer of 1918, there occurred in southern Illinois an unusual amount of fruit cracking, or bursting, just before harvest. This was especially noticeable on Stayman Winesaps. One orchardist reported a loss of 60 percent of his fruit on account of cracking and subsequent rotting.

An examination of the weather records during this period indicates the cause of this condition. There was an unusually dry, hot

[1]For a more complete discussion of this subject see Brooks and Cooley. Effect of temperature aeration and humidity on Jonathan spot and scald of apples in storage. Jour. Agr. Res., 9 (1917), 287-313.

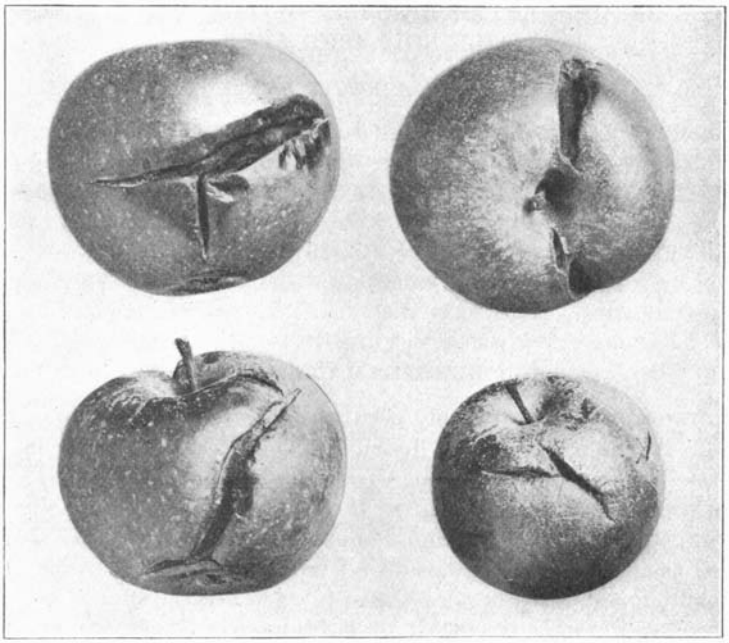

FIG. 27.—CRACKING OF FRUIT DUE TO ABNORMAL WEATHER CONDITIONS. ALTERNARIA ROT FOLLOWING CRACKING IS SHOWN ON THE UPPER FRUIT TO THE LEFT

period extending from the middle of May until the latter part of August. On August 2, the fruit was examined in a number of orchards in Johnson county, where the cracking was most severe later in the season. The fruit was quite small for the time of year and in some cases felt soft and wilted. The temperature on this date, and for several days, was over 100 degrees Fahrenheit. Heavy rains fell on August 19, and subsequently there were several good showers. The apples grew very rapidly and cracking resulted. Cracks varied in size from those one-fourth inch in extent and scarcely deeper than the skin to others extending from calyx to stem and into the core (Fig. 27). The number of cracks on a single apple varied from one to eight or ten. Some were single cracks running in the direction of the core axis, while others were at right angles to these.

Almost without exception, some rot started in the cracks before picking time. Alternaria rot frequently developed. Cracked fruit, overlooked in the orchard and packed with sound fruit, invariably developed a rot in storage. This was usually Alternaria, or soft rot.

SOME SERIOUS APPLE DISEASES WHICH MAY APPEAR IN ILLINOIS ORCHARDS

PHOMA FRUIT SPOT

Phoma fruit spot is much like Jonathan spot or an incipient stage of blotch, but there is a flecked appearance to the spot, absent in these other diseases. It is distributed thruout the New England states and has recently been reported from several localities in Illinois. It is especially common on Yellow Bellflower and Tolman Sweet. It is caused by a fungus, *Phoma pomi,* and can be controlled by applying late scab sprays.

EUROPEAN CANKER

European canker probably occurs in Illinois but has not yet been found. It has a very wide distribution, being reported from many countries in Europe, and from Australia and New Zealand. It is also fairly common in Canada and in the New England and Pacific coast regions; Ohio, New York, and Pennsylvania also report it. It is regarded as the most destructive of all fruit diseases in Europe. Many fruit and forest trees besides the apple are attacked by it.

European canker is caused by a fungus called *Nectria galligena.* The fungus attacks young and old limbs and produces two types of canker, the open and the closed. The open cankers are quite characteristic. The folds about a central opening would distinguish this disease from almost all other types of canker. Very similar cankers are frequently produced when woolly aphids gain entrance to wounds and prevent proper healing.

This canker is very destructive when it becomes established, and every effort should be made to keep it out of Illinois orchards. Suspicious cankers should be cut out and burned.

NORTHWESTERN ANTHRACNOSE

This disease is found only in the northwestern apple-growing section of the country, especially in Oregon and Washington. It not only causes a serious canker, but also attacks the fruit, producing a rot very much like bitter rot. The cankers which are produced on young branches and twigs are characteristic black, sunken, dead areas. The black appearance of the diseased area has given rise to two other names, the "black-spot canker" and "black canker."

This disease is caused by a fungus called *Neofabraea malicorticis.*

As in the case of European canker, any suspicious canker on the tree should be destroyed. Spraying and care in cutting out cankers has proved fairly successful in the control of the disease in the Northwest.

APPLE DISEASES OF MINOR IMPORTANCE

POWDERY MILDEW

Occasionally apple leaves are attacked by a surface, or powdery, mildew. The under surface of the leaf shows white, powdery masses which are rather definite in outline. The petioles and young twigs may also be affected. The leaves are usually stunted in their growth and may drop before the end of the season.

In certain humid areas, as for example, the Pajaro valley of California and the Wenatchee valley of Washington, this is one of the most serious diseases. In Illinois it is of little importance except in the nurseries, where it occasionally becomes severe enough to stunt the growth of nursery stock. This mildew occurs also on the quince, pear, and cherry.

For further information concerning the life history of a similar species, see page 109. The disease is controlled by the usual applications of lime sulfur as outlined in the spray schedule for apples, page 113.

SUPERFICIAL BARK CANKER

There is frequently a confusion in the minds of growers concerning the seriousness of the various types of cankers. When they become familiar with the blister canker thru bitter experience they are apt to regard any canker-like appearance on the limbs as a serious matter. There are superficial cankers which appear in most orchards, especially the older and less cared for ones, which at first may cause some alarm. These are well-defined, slightly sunken areas of dead outer bark which appear on the larger limbs and trunk. They vary in size from an inch to several feet in length. Black pustules similar to those of black rot, but smaller and more numerous, sometimes appear on the sunken surface. However, when the outer bark is removed with a knife, the inner bark is seen to be perfectly healthy. It is probable that this disease does little damage to the tree and it need not be feared. For the most part these superficial cankers are caused by a fungus, *Myxosporium corticolum.*

BROWN ROT

This disease is caused by *Sclerotinia cinerea,* the same fungus which is responsible for brown rot of peach, plum, cherry, apricot, pear, and quince. This disease should not be confused with black rot, altho in the first stage of the rot on the fruit it is impossible to tell the difference. In both cases the rot usually starts from a wound or worm hole and at first is brown in color and may not be zoned. The apple affected by brown rot, however, does not later show the *black fruiting pustules* seen in the case of black rot. The fact that

a rot when first appearing is brown in color often leads orchardists to call it brown rot. If the weather is exceptionally damp and cloudy, gray, velvety tufts appear on the surface of the fruit, as in the case of brown rot of stone fruits. Under normal weather conditions these rarely develop.

In New York it has been observed that about 50 percent of the rot on fruit which would ordinarily be taken for black rot, is caused by brown rot. In Illinois, very little brown rot has been found on apples, but during exceptionally rainy, late summers, it may become a serious factor. There is little cause to fear either black or brown rot in this state if worms are properly controlled and if the fruit is kept free from injury in handling.

For a description of the life history of the fungus causing brown rot, see page 87.

ALTERNARIA ROT

In seasons when Jonathan spot and bitter pit are prevalent, one of the most serious rots following these diseases is caused by a fungus belonging to the genus Alternaria. The lesions resulting from bitter pit and Jonathan spot are limited, and the dead tissues are usually quite dry and corky. Upon the invasion of Alternaria, however, the spots become larger, darker in color, the tissue beneath the skin becomes somewhat moist, and the rot extends deeper into the flesh of the apple (Fig. 26). Alternaria is slow growing and under ordinary conditions does not cause rotting of the entire fruit. When the fruit is taken out of storage, however, the rot may extend so rapidly that the fruit is completely spoiled. Alternaria also frequently enters the apple thru injuries, such as cracking (Fig. 27), and may prove a serious but comparatively slow rot.

The disease may be recognized by the olivaceous or brownish green color of the mycelium and spores which develop on the surface when the fruit is placed under warm, moist conditions, especially if the skin is removed over the diseased area.

Alternaria rot can be prevented by avoiding injury to the apples and reducing the amount of scald and similar storage injuries. Badly spotted apples should be placed on the market as early as possible. The rot does not develop under good storage conditions.

HEART ROT is caused by several fungi belonging to the wood-rotting groups. *Fomes iginarius* and *Polystictus versicolor* (Fig. 28) are the most common species.

SPONGY DRY ROT is caused by *Volutella fructi*, a rot of the fruit somewhat like Alternaria rot following Jonathan spot (Plate II, g).

PHYTOPHTHORA ROT. A downy mildew, *Phytophthora cactorum,* is known to occur on apples in Europe and America. It is rare.

PLENODOMUS CANKER. A canker-producing fungus, *Plenodomus fuscomaculans,* has been reported from Michigan. It has not been found in Illinois.

FIG. 28.—POLYSTICTUS VERSICOLOR ON TRUNK OF APPLE TREE

PEAR DISEASES

PEAR BLIGHT OR FIRE BLIGHT

Raising pears in America has become a hazardous and expensive undertaking because of the prevalence and destructive action of pear blight. While this disease also attacks the apple and quince, and occasionally the plum, it is most widely known as a pear disease. It is also commonly called "fire blight," "black blight," "spur blight," "blossom blight," "twig blight," and "blight canker." For definition of these terms the reader is referred to pages 41 and 42.

Early History.—Fire blight of pear is one of the oldest and earliest recognized diseases in Illinois. It was so mysterious in its origin and so sudden and destructive in its onslaught that it especially attracted the attention of growers. So minutely and fruitlessly was it discussed in the meetings of the Illinois Horticultural Society that finally a resolution was passed to the effect that no one should be allowed to discuss the disease in future meetings. An early discussion of fire blight appeared in the *Transactions of the Illinois Horticulture Society* for 1862.[1] It is evident from this discussion that the disease was more or less familiar to growers long before that date. Its early history in America dates back to 1794, when it was described as occurring in New York state. For further details concerning its history, see page 42.

Loss from Pear Blight.—The loss from pear blight is hard to estimate. It would be safe to say, however, that it averages yearly 25 percent of the potential bearing power of the trees in the United States. Frequently 90 percent of the blossoms in an orchard are blighted, and serious twig and spur blights cut down the bearing wood and vitality of the tree for the following year. The loss of entire trees and the destruction of whole orchards are not uncommon occurrences. The main loss, however, lies in the handicap placed on the production of pears in this country thru this disease.

The pear is relatively free from serious diseases, other than blight, and stands extremes of climatic conditions. It is a delicious and much desired fruit and yields enormous crops when in bearing. For these reasons a large acreage would be planted to this fruit were it not for the blight. In fact the pear would rival the apple in production and probably outyield this universal fruit.

Susceptibility of Different Varieties.—It has long been the hope of pear growers that a variety, or varieties, resistant to fire blight would be forth-coming, but altho many claims have been made, no variety has yet been found absolutely or even relatively immune to

[1]Trans. Ill. Hort. Soc., 7 (1862), 124-127.

the disease. In the list which follows it is understood that the resistance is only relative. The growers of Illinois regard Bartlett, LeConte, Clapps Favorite, and Flemish Beauty, as most susceptible, while Kieffer, Duchess, Koonce, Anjou, Seckel, Vermont Beauty, Garber, and Lincoln are more resistant.

Symptoms.—The spur, blossom, and twig blights on the pear (Figs. 29, 30) are similar to those described for the apple, page 43. The chief difference between apple and pear blight lies in the extent and severity of body and limb cankers produced, and the increased number of hold-over cankers in the case of the pear.

The disease extends downward from the twigs and spurs to the larger limbs and trunks (Fig. 31), where it rapidly spreads, frequently girdling a large branch in a few days, and causing it to wilt and die above the point of attack. This is true also of the trunk, in which case the entire tree dies.

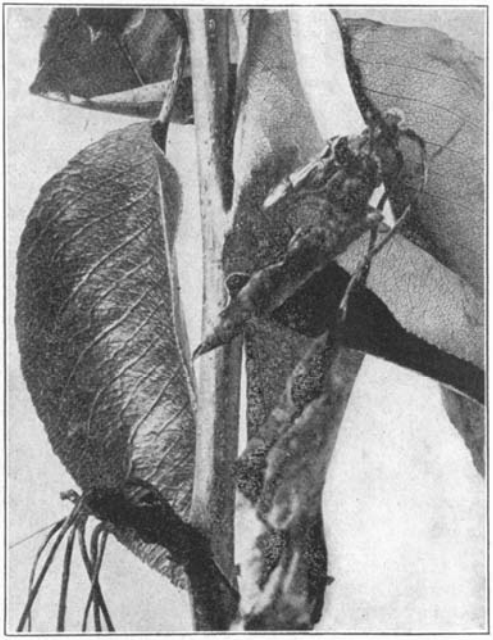

Fig. 29.—Spur Blight of Pear

Water sprouts on the body or larger limbs are especially susceptible to blight, and it is thru these that many of the cankers originate. At first the disease does not extend entirely into the cambium but causes the death of the inner bark and stops up the vessels of the phloem, the conducting tissue just outside the cambium. During damp weather in the spring slimy, grayish, or dirty brown drops ooze from some of these cankers and furnish the inoculum for fresh twig and blossom infections.

A discussion of the cause of fire blight and the life history and methods of dissemination are given under fire blight of apple, page 44.

Control.—No entirely successful methods of control of fire blight have been discovered. Some of the methods used and suggestions for reducing the amount of blight are discussed below with the idea that under certain conditions they may prove helpful.

Certain points regarding the nature of the disease should be borne in mind in connection with attempted control:

(1) It is caused by a bacterium, not by a fungus.

(2) It is usually introduced into the flower or twig in such a manner as to preclude the possibility of applying a spray for protective purposes, i. e., of meeting the organism before it enters and preventing its multiplication.

(3) After the bacteria enter the tissues it is useless to attempt to kill them by external applications of sprays.

(4) The disease is usually, but not always, insect borne.

(5) The bacteria may be transferred by wind-blown mist.

(6) Infection on twigs most frequently occurs thru the puncture of insects.

(7) When first introduced into the blossoms the bacteria multiply rapidly in the nectar of the flowers.

(8) High temperatures and dry weather are highly unfavorable for the development and spread of the disease.

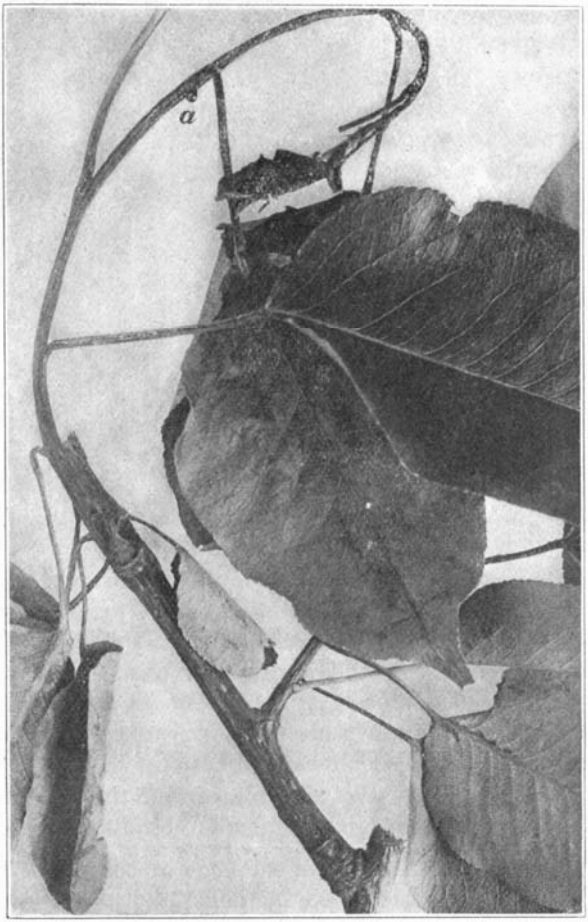

FIG. 30.—TWIG BLIGHT OF PEAR SHOWING EXUDING DROP AT (a)

Spraying.—The only effective spray against fire blight would be one which (1) as a germicide would enter the nectar chambers of the flower and prevent the development of the organism when introduced by insects; (2) as an insecticide would reduce the number of insects in the orchard; (3) as a covering germicide would meet and kill the organisms as they emerged from the hold-over cankers.

A germicide used to spray in the flower would have the following disadvantages: It might poison the ovary and prevent the set of fruit, or render the stigmatic secretions alkaline and prevent pollination. It might be injurious to bees and other beneficial insects. It would have to be applied daily to enter the blossoms as they opened.[1]

A covering germicide would have to be one of great adhesiveness and of high germicidal power which would not injure the plant tissues.

Fig. 31.—Canker on pear limb resulting from blight running down from spur

Cutting Out.—

(1) Removing Hold-Over Cankers. The elimination of all hold-over cankers by removing the diseased tissue and the included organisms would destroy the sources of infection the following year. The difficulties lie in the recognition of the hold-over cankers, in the cost of removing and treating all cankers, and in the probability of the disease being introduced from a distance or from neighboring orchards not so treated.

(2) Cutting Out Diseased Parts As They Appear in the Spring. The elimination of diseased twigs and blighted spurs as they are seen to be affected in the spring would prevent in a measure the spread of the disease. Under Illinois orchard conditions at present this is regarded as impracticable. In a small way, especially in nursery stock, it is no doubt a practical method especially if the nursery is isolated.

Application of Chemicals to Soil or Introduction into the Tree.—

(1) Application of Fertilizers.—Attempts have been made to reduce fire blight by the application of various substances to the soil. These have been in the nature either of fertilizers or of inert or poisonous chemical substances. It is recognized that nitrogenous fertilizers usually increase the amount of blight, and it is the opinion of some that potassium and phosphates decrease its severity. There

[1]Fairly successful control of blossom blight thru the use of Bordeaux was obtained by Stevens, Ruth, and others. (See Phytopath., 7 (1917), 75.)

is a basis for each of these opinions. It is well known that the succulent tissues are especially susceptible to attack and that increased nitrogen tends to produce succulent growth. The action of potassium and phosphates is explainable on the assumption that these harden or mature the tissues.

(2) Application of Chemicals to the Soil.—In the early history of this disease many fake remedies were sold to the distressed grower by unscrupulous agents. All of these were worse than useless. Other well-meaning individuals have suggested the application of wood ashes, chicken manure, lime, etc. The fact that the following year proved to be one with mild blight often led to false conclusions regarding the value of these "cures."

(3) Introduction of Chemicals into Trees.—Many attempts have been made to discover a chemical which could be introduced into the wood or bark of a tree and, thru its absorption, render the tree less susceptible to the disease, or "cure" it in case the blight was present. All such experiments have failed to attain the desired end.

While the majority of growers no longer waste their money on these worthless remedies, there are yet a few inexperienced or credulous ones who are willing to try anything recommended. Unless such recommendations are based on scientific trials and approved by those who have made a thoro study of the disease, the grower should not venture a cent in experimentation. The remedy should be demonstrated to the entire satisfaction of the grower and a money guarantee given that any damage done the trees will be paid for.

SCAB

Scab is one of the most widely distributed pear diseases in the United States. Fortunately it is not generally prevalent in Illinois and at present is of little economic importance. In California it is regarded as the most serious disease, with the exception of blight, while in the East it is sometimes serious enough to cause a marked decrease in the value of the fruit. In Ohio it is estimated that it caused a loss in 1905 of $50,000.

Pear scab is regarded by most growers as identical with apple scab on account of its very similar appearance. As a matter of fact the two diseases are caused by two different species of fungi, and scabby pear trees in the neighborhood of an apple orchard would not cause the apples to scab. The two diseases, however, are very similar in their symptoms and life histories. The same weather conditions which favor apple scab, i.e., cold, damp springs, are also favorable for the development of pear scab.

Susceptibility of Different Varieties.—In Illinois, Flemish Beauty is regarded as the most susceptible variety. Duchess, Winter Nelis,

and Seckel are frequently affected; Kieffer is apparently almost immune.

Symptoms.—The principal loss is thru the disfiguring effect of the disease rather than thru actual impairment of the quality of the fruit, altho in some cases severe cracking results. The leaves, twigs, and fruit pedicels are attacked.

On the leaves, the lesions are usually found on the under surfaces as olivaceous, velvety spots about one-fourth of an inch in diameter and more clearly defined than in the case of apple scab. The spots may also appear on the upper surfaces.

On the fruit, the disease may appear quite early, and at this stage it frequently causes a dropping of the fruit shortly after the fall of the petals. The lesions are similar to those on the apple. The diseased pears are frequently distorted by the inability of the scabbed area to grow normally, and cracking results. Scabby fruit does not keep well and is regarded by dealers as second class.

On the twig, the scab frequently appears in spots which are not very conspicuous and may be easily overlooked. The apple and pear scab differ in this respect, as the disease is rarely found on apple twigs.

Cause.—Pear scab is caused by a fungus, *Venturia pyrina.* Its life history is in every respect similar to that of the apple-scab fungus with the exception of the twig infection previously referred to. This phase of the life history is very important, however, since it furnishes a source of infection in the spring that is lacking in the case of the apple-scab fungus.

For further details concerning life history and symptoms, see apple scab, page 16.

Control.—A delayed dormant spray to kill the fungus on the twigs should be applied if trouble is experienced in the control of the disease. This should be applied as the buds are beginning to open, and if possible should be followed by a summer-strength spray (lime sulfur, 1-50) just before the blossoms are fully expanded. These two early sprays are much more effective than the later sprays. Since an additional spray for the control of the codling moth has to be applied just after the petals fall, a fungicide (lime sulfur) should be used at this time to make sure of the control of the scab. These sprays are recommended only in case scab has been troublesome in the past.

LEAF SPOT

The pear is subject to two common leaf spots, one of which will be described under leaf blight, since it is known by this term in the case of the quince, on which fruit it is much more generally found.

The leaf spot here described has not been found on the quince in this state. It is capable of doing serious damage to pear orchards

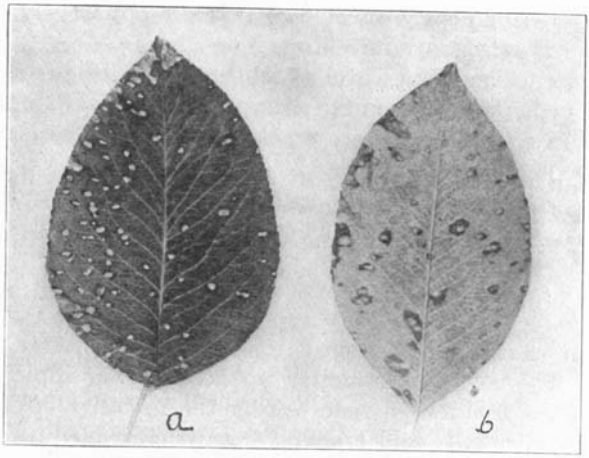

FIG. 32.—SEPTORIA LEAF SPOT OF PEAR: (a) UPPER SURFACE; (b) UNDER SURFACE

thru defoliation and is described here on this account rather than on account of any present importance in Illinois. It is known at present to be serious only in the eastern part of the country, altho it is occasionally found in Illinois, causing some premature dropping of leaves. The disease is frequently very troublesome in nurseries.

Symptoms.—The first indication of the disease is the presence of minute purplish spots on the upper surface of the leaf. The lesions appear later as well-defined, slightly angular spots from one-eighth to one-fourth inch in diameter. There is an outer zone of brown or purplish brown tissue about a grayish center (Plate I, c and Fig. 32). In this dead, gray center dots appear later in the season. The spots are usually scattered but may be so numerous as to fuse. The attacked leaves usually fall the first of August, thus reducing the vitality of the tree.

Cause.—The fungus which causes this disease is called *Mycosphaerella sentina.*

The diseased leaves fall to the ground in late summer and perithecia are developed in them the following spring. Ascospores are forcibly expelled from these, and bring about infection on the young leaves.

Control.—Should this disease become serious it may be controlled by lime sulfur (1-50), applied as indicated in the spray schedule, page 113. At present the disease is not of sufficient importance in Illinois to warrant spray applications aside from the regular ones employed.

LEAF BLIGHT

This disease is more widely distributed and more generally known than leaf spot but probably has been confused with it in the minds of most growers and horticulturists. Between 1888 and 1894 it seems to have attracted considerable attention in this country on account of its prevalence in the eastern states. The same disease is present on the quince and has caused more damage on this fruit in Illinois than on the pear.

A comparison of the leaf spot and leaf blight of pear is given in Table 3 in order that the grower may know with which of these troubles he is dealing.

TABLE 3.—COMPARISON OF LEAF SPOT AND LEAF BLIGHT OF PEAR

LEAF SPOT (*Mycosphaerella sentina*)	LEAF BLIGHT (*Fabraea maculata*)
(1) Spots angular	Spots usually circular
(2) Spots at first purplish or dark brown	Spots at first carmine-red
(3) Later, ashen gray center with several small, black dots	Center some shade of brown with single black central cushion
(4) Does not appear on fruit or twigs	Frequently causes spots on fruit similar to lesions on leaves, and elongated spots on twigs

Leaf blight is especially troublesome in the nursery, where it is most serious on pear seedlings. It frequently causes complete defoliation before the first of August.

For a description of the disease and for control measures, see quince, page 82.

DISEASES COMMON TO APPLE AND PEAR

The following diseases are so similar in behavior on pear and apple that the reader is referred to their treatment under the apple.

BLACK ROT (*Physalospora Cydoniae*) is common on pear fruit and causes cankers on the trees. The majority of the rots of unripe pears in the orchard are caused by this fungus. (See page 45.)

SOFT ROT (*Penicillium expansum*) is also common, especially on stored ripe fruit. (See page 48.)

BITTER ROT (*Glomerella cingulata*) sometimes causes serious loss in pears, especially when they are in the neighborhood of apple orchards suffering from bitter rot. (See page 26.)

BROWN ROT (*Sclerotinia cinerea*) is more common on pear than on apple and frequently causes serious losses when pears are allowed to ripen on the trees. (See page 87.)

SOOTY SMUDGE AND FLYSPECK (*Gloeodes pomigena* and *Leptothyrium Pomi*) are common during the damp seasons under the same conditions as favor the disease on apples. (See page 52.) They affect the Kieffer especially under Illinois conditions.

RUST (*Gymnosporangium globosum*) on pear, tho caused by a different species from that producing the rust of apple, is in most respects identical with it. The alternate stage is found on the red cedar, and cedar apples similar in character to those formed in the case of apple rust are developed. This disease is rare in Illinois and has never been found to be serious enough to warrant special control measures. The removal of the red cedar in the neighborhood of the pear trees will have the desired result. (See page 37.)

There is another rust of pears (*Gymnosporangium Libocedri*) found on the Pacific coast, which has its alternate stage on the incense cedar (*Libocedrus decurrens*). This rust is not likely to be introduced into the state since the incense cedar is not grown here.

PINK ROT (*Cephalothecium roseum*) occurs on fruit attacked by the scab fungus as well as on injured fruit. (See page 51.)

CROWN GALL (*Bacterium tumefaciens*) is especially troublesome in the nurseries and may cause some loss in the orchard. (See apple, page 56, and raspberry, page 122.)

QUINCE DISEASES

LEAF BLIGHT

The most serious disease of quinces in Illinois is unquestionably leaf blight, or leaf spot. It is serious in the nursery as well as in the orchards. Entire orchards are sometimes completely defoliated by the first of August, and new shoots are developed from the next year's buds in order to replace the lost foliage. The fruit is often so heavily attacked as to be rendered worthless.

The disease occurs in the United States as well as in Europe wherever the quince is grown. Both the pear and the quince are subject to leaf blight, but the quince suffers more severely. Varietal resistance has not been observed but it no doubt occurs.

Symptoms.—The disease occurs on the leaf, fruit, and twig.

On the leaves it appears in the spring as minute, reddish brown spots on the upper surfaces. These enlarge and when numerous frequently run together. The centers of these spots are slightly lighter in color than the borders (Fig. 33). The individual lesions remain

circular in outline, but on account of frequent coalescing they sometimes appear to be quite irregular. Later, a single coal-black, slightly elevated dot appears near the center of the spot (Fig. 33). The leaves turn yellow and drop during the latter part of July.

On the fruit, lesions similar to those on the leaf appear usually somewhat later in the season. The character of the fruit spots is well illustrated by Fig. 34.

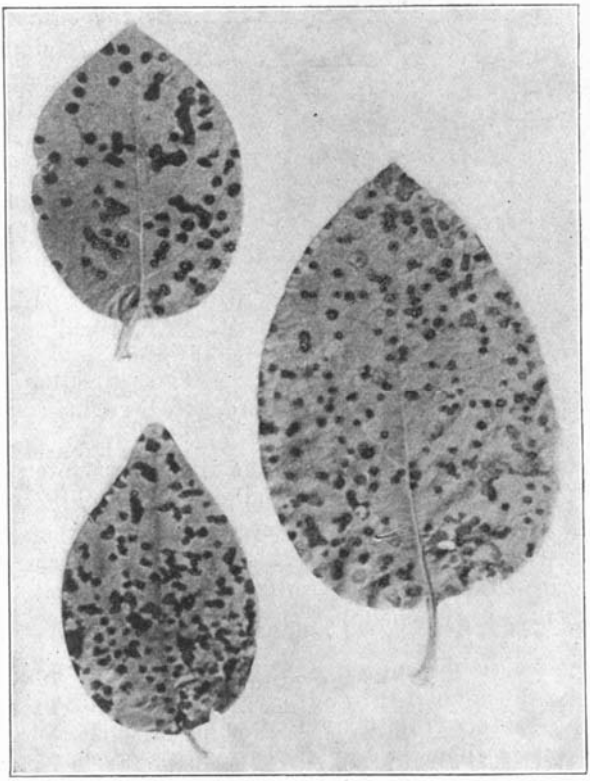

FIG. 33.—LEAF BLIGHT OF QUINCE

On the twigs the lesions are elongated and frequently girdle the twigs when the season is favorable for the development of the disease.

Cause.—Leaf blight is caused by a fungus, *Fabraea maculata.*

The fungus spends the winter in the fallen leaves and in the spring develops apothecia containing ascospores on these leaves. These ascospores are forcibly discharged and are carried by currents of air to the young foliage. Infecting the leaves, they form the spots and develop here the summer spores in acervuli, the little black areas in the center of the spots (Fig. 33). These spores ooze out in great

quantities during damp weather and appear as clear, sticky heaps on the surface of the black areas. The spores are carried thru various agencies to other leaves and to the fruit, where they produce new infections.

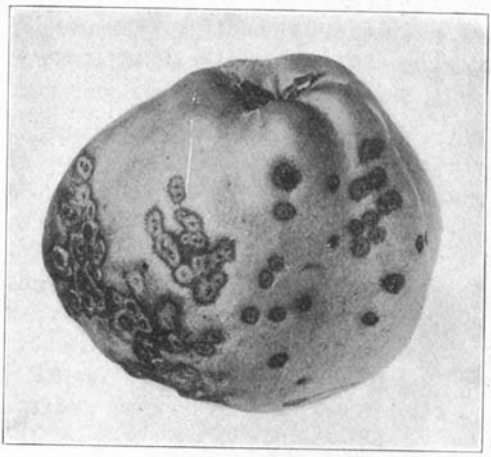

Fig. 34.—Leaf blight on fruit of quince

A striking case of reinfection was seen in an orchard near Mackinaw, Illinois. In the summer of 1918 this orchard was completely defoliated during the latter part of July. The buds of the following season developed at once, sending out fresh leaves. About the first week in August these new leaves were showing the small, purplish brown spots characteristic of the first appearance of the disease. This infection took place during relatively dry weather, as there had been no rain after the buds began to develop.

It is not known whether the conidia live over winter or whether infection may take place thru the production of conidia on the twigs on which the mycelium has overwintered.

Control.—Practical control of this disease has been obtained in other states by the use of lime sulfur, the application being made according to the spray schedule, page 113.

FIRE BLIGHT

The quince suffers from fire blight to the same extent as the pear and more severely than the apple. In many sections of the country the cultivation of this fruit has been abandoned on account of blight attacks. All varieties are about equally susceptible.

The symptoms of the disease, the life history of the organism, and control measures are discussed under apple, page 41, and pear, page 74.

The behavior of the disease on the quince is in every respect identical with its behavior on the pear. It is especially troublesome in the nursery. Careful cutting out of blighted twigs should be practiced.

PALE ROT

A common disease of quinces in the market is called pale rot on account of the light bluish gray appearance of the diseased tissue. In the fall of 1917 this rot was one of the commonest found in Illinois markets. The extent of the disease outside the state is not known, but it was described in New Jersey as early as 1892 and later from Michigan.

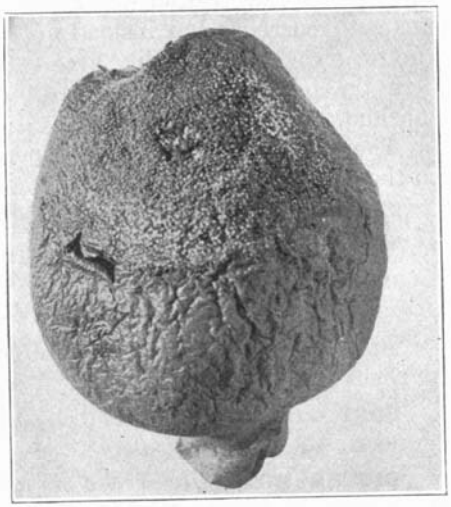

Fig. 35.—Pale rot of quince. Note white fruiting pustules and wrinkled rotted area

Symptoms.—The disease is known to occur only on the fruit and usually appears following wounds. The first indication of the malady is a small, pale, bluish green, circular spot about some injured point or originating at the calyx end on uninjured fruit. Under favorable conditions the rot spreads with remarkable rapidity, and the entire fruit is soon reduced to a much-wrinkled mummy. The rotted flesh is soft but not mushy or watery. The edge of the area is usually gray or bluish green in color but occasionally is light brown, especially in the less hairy varieties of quince. In the center of the rotted area many minute pimples appear, which increase in number and extent as the rot advances (Fig. 35). The mummy becomes dry and hard.

Cause.—This rot is produced by a fungus which has not yet been named. The pycnidia produced on the rotted surface produce pycnospores which ooze out in long, curled tendrils. They are held together by a gelatinous substance which dissolves in water. These spores germinate within a few hours when placed in water and are able to reinfect other fruit. Little is known of the life history of the fungus in nature.

Control.—The only method of control suggested is care in handling the fruit to avoid injury. The disease appears about insect punctures and following leaf blight. (See page 82.) Control of insects in the orchard will aid in reducing the injury.[1]

[1]This disease is being investigated at the Illinois Agricultural Experiment Station, and further details concerning its life history will be published at a later date.

RUST

While the rust of quince is caused by a different species than the fungi causing apple and pear rusts, it has a similar life history.

The rust fungus, *Gymnosporangium claviceps,* develops its aeciospores on the fruit and twigs of the quince, causing much more damage than in the case of the apple rust. The aeciospores infect the common red cedar but instead of forming a cedar apple as in apple and pear rust, a canker-like area is developed on the larger twigs, and here the teliospores are formed. These, thru the development of sporidia, reinfect the quince.

The control of the disease depends, as in the case of apple rust, on the elimination of red cedars (*Juniperus virginiana* and *Juniperus communis*) in the neighborhood of quince orchards. (See apple, page 37 and pear, page 82.)

DISEASES COMMON TO QUINCE, PEAR, AND APPLE

BLACK ROT (*Physalospora Cydoniae*) is found on quinces and at times causes serious rotting. (See apple, page 45.)

SOFT ROT (*Penicillium expansum*) is common on over-ripe quinces. (See apple, page 48.)

BITTER ROT (*Glomerella cingulata*) may be quite destructive on the quince. (See apple, page 26.)

BROWN ROT (*Sclerotinia cinerea*) is less frequently found on quinces than on apples, pears, and stone fruits. (See apple, page 81, peach, page 87.)

CROWN GALL (*Bacterium tumefaciens*) is frequently found in the nursery on quinces. (See apple, page 56.)

PART II

DISEASES OF DRUPACEOUS FRUITS

The drupes, including peach, plum, apricot, and cherry, have a number of diseases in common. In each case, brown rot is undoubtedly the most serious single malady. Bacterial leaf spot is frequently found on plums, peaches, and apricots, but not on cherry, while the common fungus leaf spot of cherry often appears on plum but does not affect peach and apricot. Leaf curl is a serious disease of peaches, not occurring on plums, while black knot is one of the worst enemies of plum but occurs rarely (in Illinois at least) on cherry, and is unknown on peach.

The peach is one of the most important fruits in Illinois from a commercial standpoint, while cherries and plums also are grown on a large scale. Sweet cherries have not proved a success under Illinois conditions, but sour cherries are extensively grown, especially in the farm orchards. The fact that brown rot and black knot are most serious on those plum varieties which would prove of the greatest commercial value, has been an important factor in preventing orchardists from planting a larger acreage to this fruit.

PEACH DISEASES

BROWN ROT

Loss from Brown Rot.—There is no disease of peaches so feared by the commercial orchardists as brown rot. After a crop is picked and on the way to the market the rot may start and cause loss amounting to hundreds of dollars. It is also the most destructive disease with which the wholesale and retail fruit dealers have to contend. Brown rot frequently makes the shipping of peaches over long distances a hazardous undertaking. Entire carloads of peaches often come into Chicago and St. Louis markets in such a condition as to be almost worthless.

Brown rot of stone fruits has been recognized in America for many years. It is also a serious disease in Europe and was probably introduced into this country early in the history of peach growing. It is most serious in the southern peach-growing states, but during warm, wet summers, may become very serious in northern latitudes. It has been estimated that it causes an annual loss of $5,000,000 to peach growers in the United States.

The disease produces cankers on the limbs, blights the twigs and blossoms as in fire blight of pear, and finally rots the fruit, both in the orchard and in the market. The main loss in Illinois orchards is thru rotting of fruit.

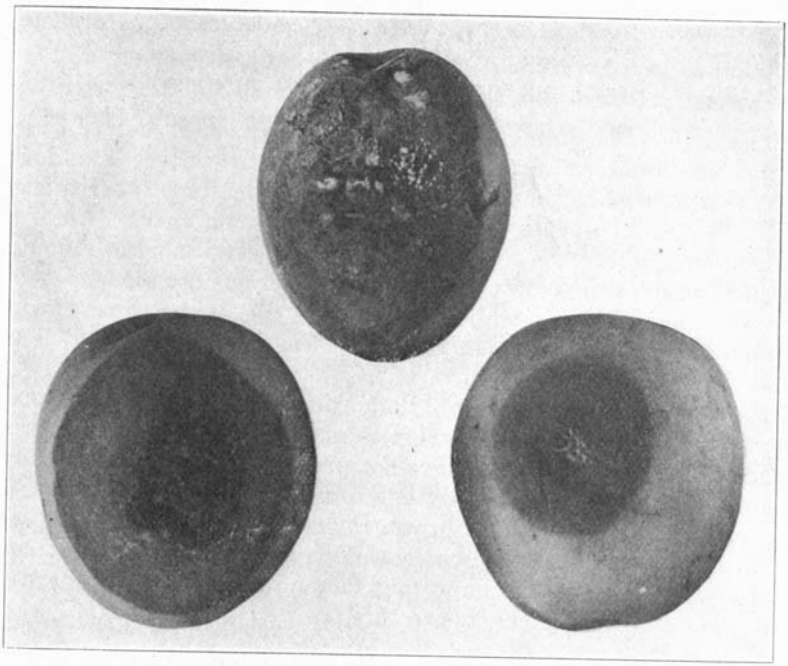

FIG. 36.—BROWN ROT OF PEACH, SHOWING VARIOUS STAGES OF THE ROT. THE FRUITING PUSTULES ARE SHOWN IN THE UPPER FIGURE

Susceptibility of Different Varieties.—Little is known concerning varietal resistance to brown rot, but light-colored varieties are considered most susceptible. All varieties grown in Illinois are quite susceptible.

Symptoms.—Brown rot *on the fruit* is well known to every one who has had the slightest experience with peaches. The orchardist may look for the first appearance of the disease on the fruit when it is about half grown. As a rule the rot appears first near some wound or insect puncture (Fig. 36, right), but as the fruit nears maturity its susceptibility to attack increases and spots may appear on the apparently sound surface. The spots at first are small, circular, grayish brown, decayed areas which rapidly increase in size (Fig. 36, left). When the spot has involved a considerable portion of the peach, gray tufts develop on the surface (Fig. 36, above). After the entire fruit has rotted, it gradually shrinks into a black mummy covered with the ashen, powdery masses.

On the twigs, blossoms, and limbs the symptoms are less familiar to the average orchardist. In the spring when the blossoms unfold, they are often attacked by this fungus and, turning brown, wither and drop off. The twigs blight in a manner similar to fire blight of pear, the withered leaves clinging to the twig. Cankers on the limbs

are not common in Illinois orchards. They are dead, sunken areas about which large masses of gum are usually found.

Cause.—Brown rot is caused by a fungus, *Sclerotinia cinerea.*

The conidia of this fungus are produced on the rotted surface of the fruit, in old cankers, and on the blighted blossoms. In addition, the old mummies which fall to the ground produce a cup-like structure, called an apothecium (Fig. 37), in which ascospores are produced in large numbers. These shoot upward in clouds in the spring and may be carried to the developing buds, where they cause blossom infection. The conidia produced on the old mummies which hang on the trees over winter may also serve as a source of infection. Spore tufts may be produced on the blighted blossoms, and these later infect the fruit. The mycelium grows from the blossoms into the young twigs and here produces twig blight, or, more commonly, the twigs are killed by the fungus passing down the spur from rotted fruit.

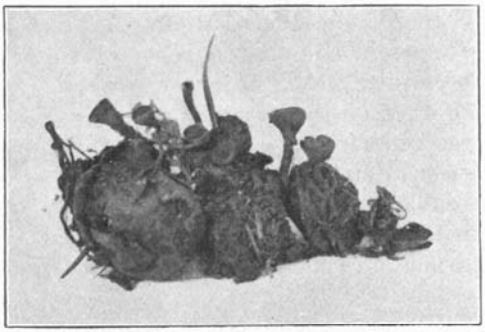

Fig. 37.—Brown rot of plum and peach. Apothecia developing from mummied fruit on the ground. Mass. Agr. Exp. Sta.

It is probable that the conidia, rather than the ascospores, are most important in producing reinfection in the spring. As the fruit becomes older, it is more susceptible to the attack of the fungus. In an orchard where there are a few old mummies, or where a few half-ripe peaches have rotted, there are thousands of spores floating about in the air. A few warm, damp days favorable for the growth of these spores on the surfaces of the peaches will produce a heavy infection.

If, when the fruit is harvested and placed in cars for shipment, a few half-rotted peaches are allowed to be packed in each basket, spores are quickly produced in the damp, heated atmosphere and are scattered thruout the basket, where they quickly infect the remaining fruit. This process is aided when there is any delay in getting the fruit into iced cars or when it is held in transit at any point in warm cars.

In the market the spores are usually abundant, since all stone fruits are subject to this disease and are constantly rotting in both wholesale and retail markets. As a rule, however, the source of infection in the market can be traced back to the orchard or to the cars in which the fruit is shipped.

Control.—Orchard sanitation cannot be overemphasized in discussing control measures for brown rot. Mummies should be removed

from the trees when pruning. It is not necessary to carry these from the orchard if cultivation is practiced, since early plowing and stirring the soil prevents them from producing the apothecial stage.

In addition to the dormant spray for controlling leaf curl, self-boiled lime sulfur should be applied as indicated in the spray schedule, page 113. It is usually unsafe to use commercial, or home-cooked lime sulfur, altho many growers in Illinois have applied this successfully. The dormant spray may be used up to the time the buds begin to swell.

BACTERIAL SHOT HOLE

Origin and Distribution.—A disease not previously known to peach growers in Illinois was reported from the southern part of the state as causing severe injury during the summer of 1915. It had been observed on the leaves as early as 1912 near Centralia.[1] This disease was reported in 1915 as affecting fruit, leaves, and twigs, causing serious defoliation and a peculiar surface cracking of the fruit. The trouble was identified as the recently described shot hole, or black spot, of peach. Since that date it has been found to be quite common thruout the state but it is especially destructive to southern Illinois orchards.

Bacterial shot hole occurs on the peach, apricot, nectarine, and plum. It is most injurious on the peach and plum. It is found in all peach- and plum-growing regions of the United States.

The disease is apparently of American origin and to date has been found only in this country. It has been known for only about fifteen years, but was probably confused with other shot-hole diseases previous to that time. Growers in Illinois state that they never saw the disease on the fruit before 1915. Its unusual severity that year seems to have called it to the attention of many orchardists. The disease was first noticed in 1903 on Japanese varieties of plums from central Michigan. In 1904 it was described as occurring on peach leaves in Connecticut.

Loss from Bacterial Shot Hole.—The bacterial shot hole is one of the most destructive foliage diseases of peach. It may cause almost complete defoliation early in the season and thus injure the subsequent growth of the tree. The disease seems to be more severe in warm, humid regions than in cool, dry sections, and worse on soil of low fertility than on soil having a high nitrogen content. In southern Missouri it has been found impossible to grow certain varieties of plum on account of this disease.

The injury to the fruit also is often very serious, and growers have reported that it has caused a large percentage of their fruit to fall early in the season. Other factors, however, may have influenced this drop.

[1]Letter from John A. Gage, Texico, Illinois.

Symptoms.—The disease is found in the leaves, fruit, and twigs.

On the leaves, the first evidence of the disease is a small circular or somewhat irregular area, a little lighter in color than the surrounding tissue. This later becomes darker in color and may turn purple or brown (Fig. 38). Frequently before there is much change in the color of the spot, a line of cleavage develops around it, and when the leaf is bent in the hand, the central area separates entirely from the surrounding tissue and falls out. This central area normally remains

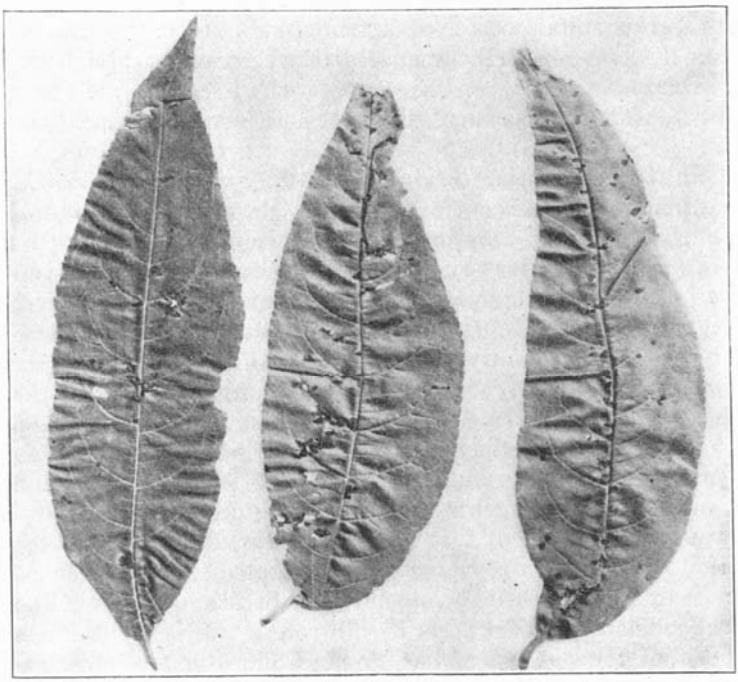

FIG. 38.—BACTERIAL SHOT HOLE OF PEACH. IN MOST CASES THE CENTRAL AREA HAS NOT YET FALLEN OUT

in place for some time after it is separated, then turns brown or black, and finally falls out. This gives the shot-hole appearance to the leaf.

Frequently the cutting off of the diseased central area checks the spread of the disease from this point, but in many cases another infected ring is formed about the central opening, which in turn is cut off from the surrounding tissue. Badly infected leaves soon turn yellow and drop off. It is to be noted, however, that a large number of leaves drop from diseased trees without being infected, at least without showing spots.

On the twigs, the first indication of the disease is a small gray area on the current year's growth. These spots enlarge and as they do so

become elongated and darker in color. In favorable seasons the entire tip of a twig may be blackened and killed.

On the fruit, the disease causes first a very small purplish spot about one-sixteenth inch in diameter. Over this spot the skin cracks, and since the spots are usually very numerous the cracks often join and extend over the entire side of a peach, forming a sort of network. Usually, broad, rather deep fissures extend across the whole infected area. As a rule the cracks do not extend below the corky layer under the epidermis of the fruit, but the whole effect is to render the peach rough and unsuitable as No. 1 fruit. Furthermore, the diseased peaches do not ship well, because cracked fruit is especially subject to brown rot.

Cause.—The organism causing shot hole is a bacterium, *Bacterium Pruni.*

From the information obtained from the reported experiments and observations of numerous investigators, we are able to present the entire life history of this organism. However, there are a number of points in this life history which are not fully established and need further study; for example, the exact manner of the transference of the organisms from the diseased to the healthy tissues.

The bacteria evidently winter in the cankers on the twigs of the previous year. The organisms also winter in the tissues of the bud, and here is probably the chief source of infection. About the first of May, or a little later, the bacteria are transferred from the cankers, and probably from the buds, to the young leaves, and later to the fruit and twigs. The agents which carry the disease are insects, wind, and water. It is evident that water is an essential factor in the final infection. It has been repeatedly demonstrated that the bacteria gain entrance to the leaf thru the stomates, or breathing pores of the leaf, and the stomates and lenticels of the young twigs. It is interesting to note that the peach leaf has stomates only on the lower surface, the upper surface being entirely devoid of breathing pores. All infection, therefore, must take place on the lower side of the leaf.

After gaining entrance to the interior of the leaf, branch, or fruit, the bacteria multiply very rapidly and live at the expense of the host cells, which gradually turn brown and die. After growing thruout the season on the twigs, leaves, and fruit, the bacteria, in all probability, die in all tissues except in some of the cankers on the twigs and in some buds. Here the bacteria hibernate and cause reinfection in the spring.

It has been demonstrated that sunshine is germicidal to these organisms when on the surface of the tissues. But since it requires only a few hours at most for the bacteria to travel from one place to another and become established within the tissue, it is possible that infection may take place even in the driest seasons. The period of

incubation is from five to seven days under favorable conditions. This means that the bacteria must begin multiplication in a short time after entering the stomates. The bacteria first multiply within the substomatal chamber without invading the tissue of the leaf.

The weather is a most important factor in the progress of the disease. If the spring is warm and damp the disease may appear in April; in other years it may not appear until August. A temperature of 70 to 80 degrees Fahrenheit is the best for the growth of the bacterium. Cold weather retards the growth of the organism and interferes with its dissemination. In dry seasons the injury from this disease is slight, especially if the spring has been cold. This factor promises to be one of the saving features for the practical peach grower, since the summers, in the peach-growing portion of this state at least, are relatively dry.

Control.—Spraying, up to the present time, has proved ineffective against this disease. It has been found possible to control it to some extent by the application of nitrogenous fertilizers and by cultivation.

Experiments conducted in southern orchards by the United States Department of Agriculture indicate that the application of three pounds of sodium nitrate early in May, followed immediately by cultivation, will hold the disease in check, even when surrounding orchards not so treated are almost completely defoliated. Any treatment that adds vigor to the tree seems to aid in the control of the disease. Application of nitrates may no doubt be made earlier in the season than suggested by the United States Department of Agriculture, with equally successful results.

PEACH SCAB

Most peach growers are familiar with the disease known as scab, or "freckles," altho few realize the losses they sustain from imperfect control of this malady. Some orchardists, in fact, regard it as a natural coloring of certain susceptible varieties, and compare it to the freckles which appear on the faces of individuals of a sandy complexion during the summer. This comparison is strengthened in their minds by the fact that scab most frequently appears on the upper or sunny side of the fruit. According to some of the older orchardists, scab has been known in Illinois since the beginning of peach raising in the state. The first definite record we have, however, is a collection made by F. S. Earle at Cobden, Illinois, in 1881. The disease is found wherever the peach is grown, both in this country and abroad.

Nature of Loss from Peach Scab.—The market value of scabby peaches is reduced thru (1) the spotting, which renders the fruit unsightly, (2) the misshapen appearance of the fruit, (3) direct cracking over the diseased area, which often extends inward to the stone,

(4) the added chance of loss thru invasion of brown rot, and (5) the buyers' knowledge that scabby fruit is unevenly ripened and subject to internal breakdown. There is also a loss in the orchard caused by premature dropping and rotting.

Susceptibility of Different Varieties.—Varietal susceptibility to scab is well marked but is dependent in part upon the period of ripening. In general, the early maturing varieties suffer less than the late ones, while the midseason varieties are intermediate. Early Crawford, Carmen, and Hiley are rarely injured, while Elberta, Hale, and Belle are moderately susceptible but may be severely attacked if conditions are favorable to the disease. Fox Seedling, Late Crawford, Edgemont, and Alexander may also be classed as moderately susceptible. Heath, Salway, Bilyeu, and Tennessee are notoriously susceptible. The disease is more serious in southern than in northern orchards, and the fruit in low-lying orchards is more severely attacked than in orchards of higher altitude. Orchards in regions of high humidity suffer more than those in arid sections.

Symptoms.—The character of the disease varies with the severity of infection.

On the fruit, when first observable, the diseased areas are small, poorly defined, olivaceous spots less than one-sixteenth inch in diameter, usually appearing on the upper or exposed surface. When these spots have developed for a few days they appear as distinct, circular, dark-olivaceous lesions usually from one-sixteenth to one-eighth inch in diameter (Fig. 39). They may be numerous and almost in contact on the upper face of the fruit, more scattered on the sides, and entirely absent on the protected lower face. When infection is severe these individual spots merge, forming a uniform, dark-olivaceous, velvety blotch over the entire exposed surface, and frequently covering one-half of the fruit (Fig. 39). The blotch is superficial, never penetrating below the epidermal layer of cells, but the effect on these cells prevents normal development and results in misshapen fruit. An extra thick, corky layer of cells is produced below the surface of the scabbed area, forming an undesirable tough skin. The inability of this skin to expand with the rapid growth of the peach causes the abnormal shape and cracking.

On the twigs, infection is indicated by light brown, oval lesions about one-eighth by one-fourth inch in diameter, which later enlarge and become dark brown. The diseased area is slightly raised and at the edge there is a peripheral ridge of almost normal color. The injury on the twigs, as on the fruit, is entirely superficial. In the spring olivaceous, velvety dots appear on the surface of these lesions. These twig lesions are first evident on the young tender twigs of the current year at about the time the spots appear on the fruit. They are usually not plainly evident, however, until later in the season.

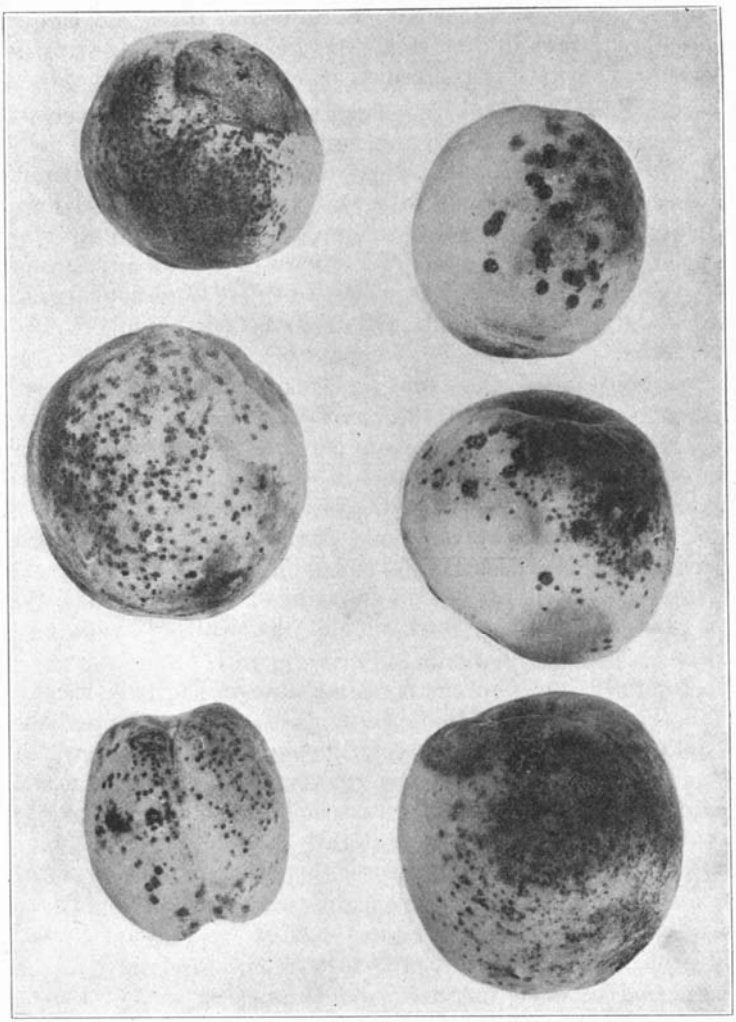

FIG. 39.—PEACH SCAB

(Photographed by G. H. Coons, Michigan Agricultural Experiment Station)

In some cases they are so numerous as to coalesce, giving rise to large, irregular-shaped areas covering the entire surface of the twig for some distance. While the disease on the twigs is of great importance from the standpoint of the wintering of the fungus, the direct injury is not great on account of the superficial character of the growth.

On the leaves, the lesions first appear on the under surfaces as ill-defined, angular, pale green areas which later become dark green.

The individual spots are usually quite small, rarely developing beyond one-fourth inch in diameter. On the midrib, long narrow lesions are developed, usually dark brown in color.

Cause.—Scab is caused by a fungous parasite, *Cladosporium carpophilum*. It grows beneath the cuticle of the fruit and twig and probably absorbs nourishment from the epidermal and subepidermal cells. As a result of its growth several layers of corky cells are produced by the host, giving rise to the tough skin and preventing normal expansion of the diseased area. The fungus produces cushions of cells beneath the cuticle and finally pushes it aside. Conidiophores are developed on this cushion and give rise to large numbers of olivaceous conidia.

It has been stated that infection takes place for the most part on the exposed surfaces of the fruit. The conidia are carried by water to the fruit, and on the unexposed surfaces of the fruit are prevented from coming in contact with the epidermis by the hairs which develop so abundantly on the peach. On the exposed surfaces, however, the rain and other agents gradually wear off many of the hairs and the surface becomes wettable and open to infection. Spores are produced thruout the season on twigs or on the fruit, so that infection may take place at any time if the fruit or twigs are in a condition to become infected.

The fungus winters in the mycelial state in the twig lesions, and the small olivaceous dots seen on the surface in the spring and summer of the following season are the conidiophores and conidia which continue to be produced thruout the growing season. The conidia, tho light and powdery in character, are not ordinarily carried by the wind but by water. They cling tightly to the conidiophores until moistened. It is probable, therefore, that the conidia are carried by rain and wind-blown moisture from the twigs to the fruit, from fruit to twigs, or from old twigs to the twigs of the current year. The conidia probably do not live over winter.

The period between infection and the appearance of the disease on the fruit is remarkably long. In the case of such diseases as apple scab and blotch, the incubation period is from ten days to two weeks, while in peach scab it is rarely under three weeks, and probably averages from a month to six weeks. Infection does not ordinarily take place until at least one month after the petals fall, and for this reason earlier applications of spray are not necessary in the control of scab.

Control.—Since scab is fairly easy to control by spraying and since spraying is necessary for the control of brown rot in Illinois, there is no reason why growers should allow this disease to cause serious loss. Sprays applied as indicated in the schedule on page 113 will control scab.

PEACH LEAF CURL

In unsprayed orchards, peach leaf curl is one of the most destructive diseases. In some orchards it has become so serious as to cause the owners to discontinue growing peaches on a commercial scale. It is not now regarded as so important in the large commercial orchards because it is easily controlled.

Origin and Distribution.—Leaf curl has been known since the early part of the nineteenth century and was among the earliest recognized peach diseases in the United States. It is distributed over the world wherever the peach is grown but seems to be most serious in the cooler regions. It is primarily a disease of the peach and nectarine.

Loss from Peach Leaf Curl.—The loss from leaf curl is caused thru defoliation, which in turn induces failure of the tree to hold and develop its fruit. Frequently the tree becomes so completely defoliated that new shoots are sent out the same season, thus impairing the vitality of the tree. Twigs also are killed, and the final result of several successive seasons of injury is the death of the entire tree. The loss in this country is estimated at about $3,000,000 per year.

Susceptibility of Different Varieties.—There is some varietal difference in susceptibility to curl, but it is not marked. Elberta, Hale, and Carmen are regarded by growers in Illinois as the most susceptible varieties. Seedling peaches always show marked susceptibility.

Symptoms.—Leaf curl is usually confined to the current year's growth, involving twigs, leaves, and blossoms. It rarely extends downward upon the growth of the previous season. The common name, leaf curl, very aptly characterizes this disease. In the spring when the leaves first appear they are much thickened, especially along the midribs and veins. As they develop, the entire leaf blade becomes puffed and folded, the edges curling inward so that the under surface of the leaf is a series of concaved chambers. This roughened character may be developed on only a part of the leaf. The diseased leaves acquire red or purplish tints, which are very characteristic of this malady. They finally turn yellow or brown and fall off. On the twigs the disease causes a swelling which is noticeable only on badly affected branches. A comparison with healthy trees shows that these twigs are stunted in their growth. The dormant buds on defoliated trees frequently start new growth.

Cause.—The fungus *Exoascus deformans* is the pathogene causing leaf curl. It grows in the tissue of the leaf but does not kill the cells at once. In fact it stimulates them and causes an abnormal growth which results in a swollen and thickened condition of the leaf blade. These cells do not develop the green coloring matter (chlorophyll) which is essential for the proper functioning of leaves.

The abnormal condition created by the growth of the fungus finally causes the dropping of the leaf, even tho its tissues are not dead.

Before the leaves fall, the mycelium grows along under the cuticle of the leaf on both the upper and the under surface and produces small sac-like structures, the asci, in which the spores (ascospores) of the fungus are produced. These spores are not liberated directly but bud in the ascus, producing many more small spore-like bodies which are liberated by the rupture of the top of the ascus.

The remainder of the life history of this fungus is unknown. It is probable, however, that some of these minute secondary spores lodge on the surface of the twig and in the scales of the buds and reinfect the young leaves the following spring. The fact that either fall or winter dormant spraying controls the disease, is used as an argument against the old belief that the mycelium can winter in the twigs. The dormant spray would not be able to penetrate the twig to kill this hibernating mycelium. It is well known that yeast-like organisms similar to the budding forms of the leaf-curl fungus pass the winter in the soil under the fruit trees and are transferred in great numbers to the fruit the following season. There is no reason to doubt a similar method of wintering in the case of the spores of the leaf-curl fungus on the twigs and among the bud scales of the peach.

Control.—Fortunately the control of leaf curl is a very simple and relatively inexpensive process. A single application of any good fungicide, either in the fall or in the spring before the buds open, will control the disease. The dormant spray of lime sulfur ordinarily applied in Illinois orchards in the early spring will control it perfectly. When no scale is present this process may be made less expensive by applying a 1-15 spray. It is very important that every bud be coated.

PEACH YELLOWS, LITTLE PEACH, AND PEACH ROSETTE

The three diseases here described are frequently referred to as physiological diseases because the causative agent is unknown. There is good evidence, however, that these troubles are not caused by abnormal climatic or nutritive conditions and, consequently, would not fall under the head of true physiological diseases.

Peach Yellows is the best known and earliest described of these three diseases of the peach and on account of its mysterious and destructive nature has received a great deal of attention. It was known as early as 1791 in the eastern states and since that date has killed millions of trees, causing in some sections the abandonment of peach growing altogether. From 1884 to 1890 more than one-half million trees were destroyed in one county in Michigan, There seems to have been definite periods during the last century when the disease was

TABLE 4.—COMPARISON OF PEACH YELLOWS, ROSETTE, AND LITTLE PEACH

YELLOWS	LITTLE PEACH	ROSETTE
(1) Fruit ripens prematurely. Red spots on surface and streaks in flesh	Fruit ripens two weeks later than normally. ⅓ to ½ normal size; bitter flavor; stringy flesh	Fruit ripens normally. Taste and coloring almost normal
(2) Numerous secondary shoots, bearing small, yellowish or yellowish green leaves. Leaves slender and drooping	Development of secondary shoots not pronounced. Leaves ½ normal size, yellowish green, drooping	Rosettes formed by development of large number of winter buds into short shoots with many small leaves
(3) Cause unknown	Cause unknown	Cause unknown
(4) Infectious	Infectious	Infectious

especially destructive. It is known to occur only in North America and is most destructive in the older peach-growing sections along the Atlantic seaboard and in Michigan. There has been little damage from peach yellows in Illinois, and the disease should not be allowed to establish itself.

The symptoms of yellows are given in Table 4. The red spotting and premature ripening of the fruit are the most characteristic symptoms. The development of the numerous clusters of shoots with their pale yellow foliage may not appear until the second year after the disease has started, but always accompanies the other symptoms. Trees suffering from yellows never recover, usually dying within two or three years.

Little Peach.—The name of this disease indicates one of the principal symptoms. The fruit matures from ten days to two weeks later than normal fruit and is always about one-half as large. The leaves are small, inclined to droop, and are "off color." The death of the tree is usually more gradual than in the case of yellows, the upper and outer branches dying first.

Little peach was first described as causing damage in Michigan about 1893 and at that time was unknown in the East. Later it was described from New Jersey. This disease is more serious in some sections than yellows or rosette.

Rosette.—This disease was described as occurring in Georgia about 1879. It has a more southern range than peach yellows and little peach, and rivals them in destructiveness.

The disease is characterized by the growth of many more of the winter buds than normally develop. These grow out as short, stunted shoots with numerous leaves of a greenish yellow color. The abnormal number of shoots and their stunted growth give the whorled or rosetted appearance from which the disease gets its name. The foliage falls prematurely and the older leaves are inrolled at the edges. The tree usually dies within six months to two years after the first symptoms occur.

Cause of Yellows, Little Peach, and Rosette.—Many theories have been advanced in the past to account for these diseases. Among the supposed causes are: (1) fungi or bacteria, (2) insects, (3) climatic conditions, such as winter injury, drouth, or excessive rainfall, (4) nutritive conditions, such as too little or too much of some essential nutrient (phosphorus, potassium, nitrogen, etc.), and (5) faulty orchard practices, such as excessive cultivation, crowding of trees, overbearing, and planting too deeply.

Experiments and observations extending over a long period of years and under almost every conceivable condition of orchard practice and soil treatment make it safe to assert that none of these factors is the direct cause of any of the diseases here described. There is evidence that they may be caused by organisms of such minuteness that they cannot be seen with the highest-power microscope. This belief is based upon the fact that all three diseases can be transferred from one tree to another by grafting or budding diseased stock on healthy stock. The diseases are, therefore, infectious; but this fact does not prove beyond question that living organisms are present.

Control.—The control measures for the three diseases are the same, since they are based on their infectious nature.

The affected trees should be dug up and burned at once, whenever any of the diseases appear in an orchard. If trees appear with symptoms similar to yellows, little peach, or rosette, they should be carefully watched, and in no case should tools with which they are pruned be used to prune other trees without being carefully sterilized.

In the nursery great care should be used to get buds and scions from trees known to be healthy, and since it is known that diseased seeds also carry the inoculum, the seeds selected for growing stocks should be obtained from trees known to be free from disease. This is of importance to the nurseryman from the standpoint of economy, since peach stones from afflicted trees have a very weak power of germination.

Legislation compelling the destruction of all diseased trees is an essential control measure. Such a law was passed in Michigan in 1875 and has served to reduce the loss in that state very materially. Spraying, applications of various fertilizer combinations, and other soil treatments and pruning practices are ineffective as control measures.

PLUM DISEASES

BROWN ROT

Loss from Brown Rot.—Brown rot has caused such losses in the plum orchards of the state that many growers have entirely abandoned this fruit. In the *Transactions of the Illinois Horticultural Society* during the last twenty years, one frequently finds statements such as these: "My plums were a complete failure this year on account of

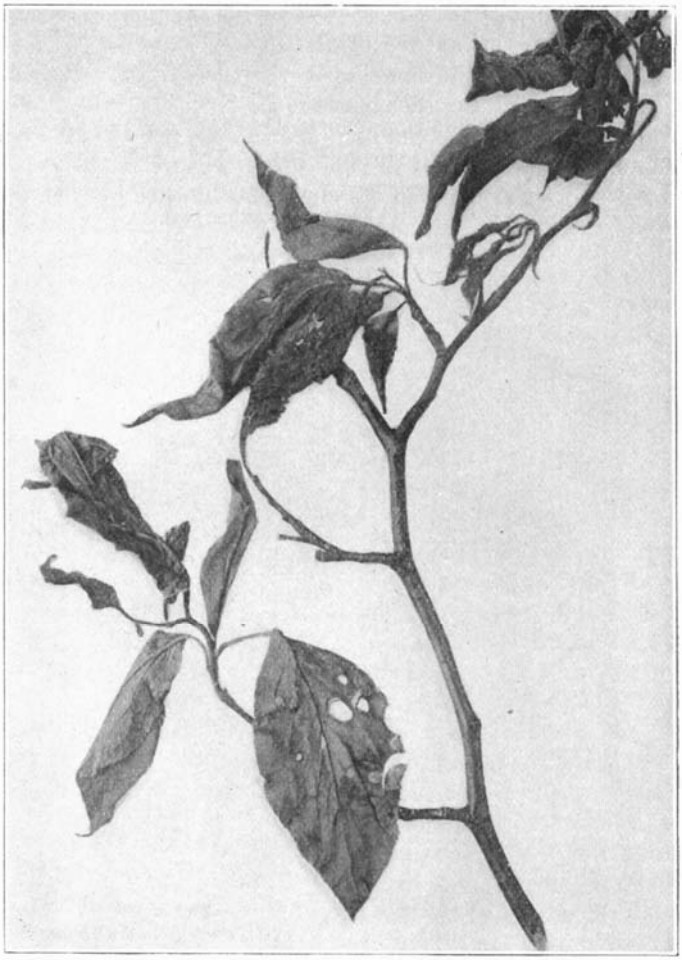

FIG. 40.—BROWN ROT OF PLUM CAUSING TWIG BLIGHT AND SHOT-HOLE EFFECT ON LEAVES

rot''; and, ''I sprayed with Bordeaux according to directions but lost over half my crop from rot.''

In Illinois, brown rot is more virulent on plums than on peaches or cherries, altho the same organism is responsible in all cases. It may be that peach growers have learned to control the disease more successfully.

Susceptibility of Different Varieties.—Most varieties of plums grown in this state are more or less subject to brown rot but the blue Damson and those varieties which grow clustered and in contact on the branches suffer most severely. Abundance and the Japanese plums are especially susceptible.

Symptoms, Cause, and Control.—The life history of the fungus, *Sclerotinia cinerea,* the nature of the injury caused by it, and the methods of control are the same as in the case of the peach and the cherry. (See page 87 for the discussion.)

A twig blight of plum often results from the growth of the fungus on the tender shoots (Fig. 40). The plum is more liable to be rotted on the tree, and on account of its clustering nature and its tendency to cling to the tree in mummied condition (Fig. 41), the disease involves a larger percentage of the fruit and spreads more rapidly than the rot on peaches. It is especially prevalent during damp, warm seasons.

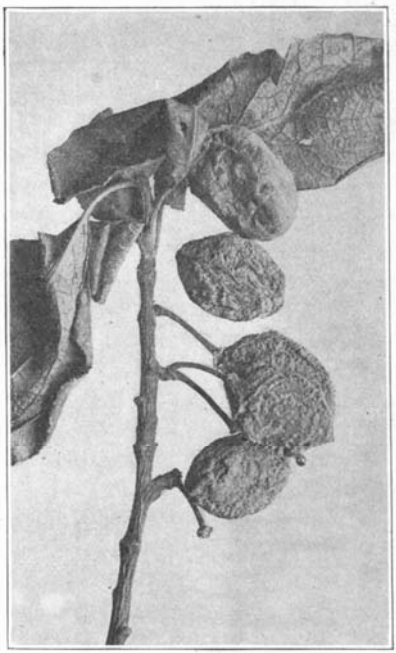

Fig. 41.—Brown rot of plum, showing mummied fruits clinging together on the fruiting twig

Thinning the fruit on the tree before it ripens to prevent contact, and pruning to open up the tree, aid in checking the disease when spraying does not prove entirely successful.

BLACK KNOT

Loss from Black Knot.—Black knot ranks second in destructiveness among plum diseases in the state. It is confined to woody portions of the tree, and thus the damage is entirely in the loss of bearing wood. However, an entire orchard of susceptible varieties may be ruined in two or three years after the first appearance of the disease.

Origin of the Disease.—Black knot has been known in America since the early part of the last century but for many years was confined to the eastern United States. In 1879 it appeared near Cincinnati, and was probably introduced into Illinois near that date. The disease is supposed to be of American origin.

Susceptibility of Different Varieties.—Certain varieties, such as Lombard and Damson, are no longer grown in some sections because of their susceptibility to this malady. Black knot attacks both wild and cultivated plums, but there is a marked difference in susceptibility in varieties. The Wild Goose group of American plums is not commonly attacked, while among the Domestica group nearly all varie-

ties are susceptible. Japanese varieties are susceptible but less so than the Domestica group. In the eastern and southern states the cherry is seriously affected by black knot but it rarely occurs on varieties grown in Illinois.

Symptoms.—The elongated black knots on the smaller limbs (Fig. 42) are usually the first indication of the disease observed by the grower. These knots are usually from one-half inch to six or eight inches in length and from one-fourth inch to an inch and a half in diameter. They ordinarily appear on only one side of the limb but may encircle the branch. As a rule they are more abundant on the smaller twigs, but as the disease becomes more severe they may appear on many of the larger branches, especially near the points where small twigs have been produced. The knots are greenish in color and quite soft in texture when first formed but become coal black and hard later in the season. The old knots often harbor insects which bring about the death of the twigs if the disease does not.

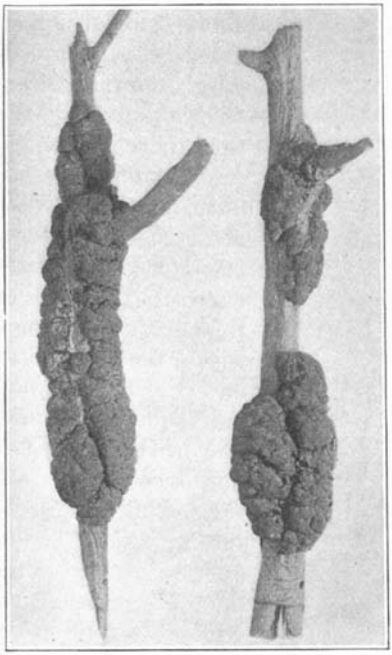

Fig. 42.—Black knot of plum

Frequently a pink mold is observed covering the knots during the summer or fall. This is not a stage in the life of the black-knot organism but is *Cephalothecium roseum*, the fungus which frequently follows the scab of apples.

Cause.—The fungus which causes black knot is called *Plowrightia morbosa.*

In the spring the ascospores from the knots formed during the previous year are discharged and carried to all parts of the orchard or to neighboring orchards. The spores, alighting in the crotches of small limbs or in the axils of buds, germinate and produce a mycelium which enters the wood. The fungus is not merely a wound parasite but can enter thru uninjured tissues. The mycelium grows thruout the bark and down to the cambium, stimulating the production of cells to such an extent as to form the extensive galls characteristic of the disease. These galls are made up of both host and fungous tissue.

In the summer following spring infection there is little indication

of the disease, but the swelling may be plainly evident in the autumn. The following spring sees a rapid growth of infected tissue, resulting in a rupture of the outer bark, and exposure of the yellowish inner bark and the wood beneath. The fungus then develops rapidly, grows to the surface, and produces an olivaceous layer of conidiophores and conidia. These spores are not known to produce infection.

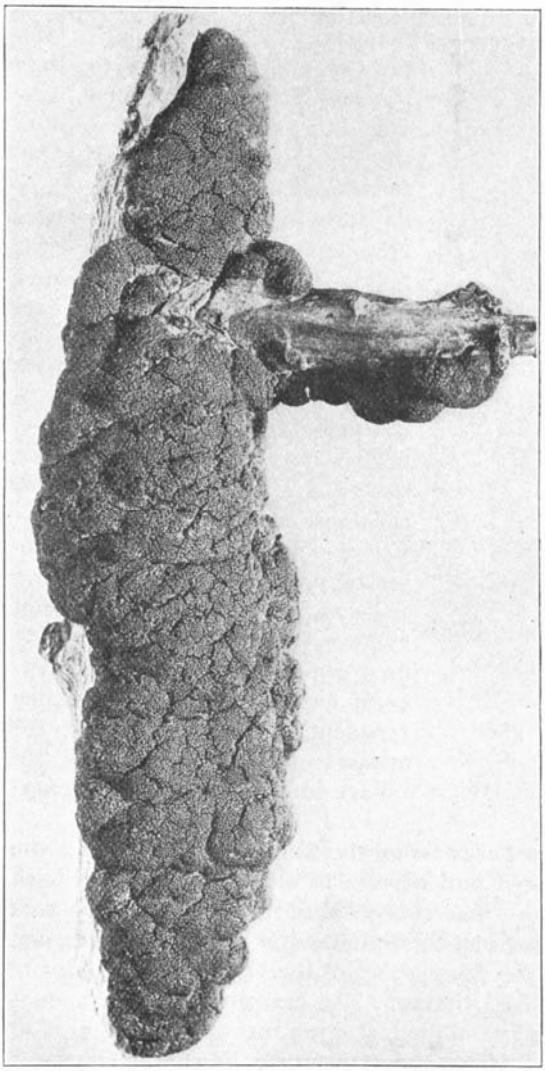

Fig. 43.—Black knot of plum, showing minute elevations below which perithecia are developed (Enlarged)

During the summer the galls enlarge somewhat and assume a coal black, roughened appearance. On the surface of the knots at this time there may be observed numerous minute, closely crowded, hemispherical elevations (Fig. 43) which mark the location of the perithecia formed within the black outer covering of the knot. During the winter and early spring, asci and ascospores are formed in these perithecia. Thus the production of ascospores takes place the second winter after infection. After the discharge of the ascospores the old knots cease functioning, but if the limb is still alive the fungus may grow in either direction from the original infection. .

Control.—Black knot once established in an orchard or in a neighborhood is difficult to control. Promptness in cut-

ting out and burning the knots as soon as they become evident in the autumn or early winter is perhaps the most effective way to eradicate the disease. None should be overlooked since thousands of spores will be produced on a single knot. Badly diseased trees should be cut down and burned.

If wild plums are growing in the neighborhood, they should be examined and, if infected, should all be destroyed.

Those varieties known to be exceptionally susceptible should not be grown, and if a fairly susceptible variety is planted, it should be watched more carefully than those known to be relatively immune.

Some care should be taken to secure trees from a section of the country known to be free from black knot, and if possible the orchard should be planted at some distance from any infected orchards.

Spraying with Bordeaux mixture has been recommended in some sections of the country, altho it has not proved uniformly successful. The applications should be begun the latter part of March and continued at least thru May and early June. The applications should be about two weeks apart.

BACTERIAL SHOT HOLE

Loss from Bacterial Shot Hole.—This disease is more generally known on the peach than on the plum, altho when the latter is attacked the injury is probably greater than on the peach. There is no record that severe epiphytotics of this shot hole ever occurred in this state, but since the disease has done severe damage to the peach there is reason to believe that it will also cause serious loss of plums should conditions be favorable for its development.

Susceptibility of Different Varieties.—The American varieties of plum are regarded as relatively immune, while the Japanese are especially susceptible. Chabot, Red June, Abundance, and Burbank are the varieties considered most susceptible, while Arkansas, Damson, Lombard, Wild Goose, and Yellow Egg are relatively immune.

Symptoms.—On the leaves, a shot-hole effect similar to that in peaches is produced, but the areas involved are usually larger and consequently greater damage results. *On the fruit,* black spots appear. These spread and many superficial cracks are produced over the diseased surface, favoring the entrance of rot-producing fungi. *On the twigs,* perennial cankers are formed, especially on Abundance and Burbank varieties.

For further details concerning this disease, see page 90.

RUST

The stone fruits are subject to a rust which appears only on the leaves. It has not been commonly reported in Illinois but will be

described because in the past it has appeared in epiphytotic form in neighboring states. Rust is most destructive in the southern states. In 1889 there was a serious outbreak in Iowa. Chippewa plums are said to be especially susceptible.

Symptoms.—On the underside of the leaf, small, round, light brown, powdery, scattered pustules are formed from midsummer on. The diseased areas are not dead, nor is the normal color of the leaf changed. When the attack is severe, defoliation frequently results.

Cause.—Rust is caused by a fungus, *Puccinia Pruni-spinosae*, which has its aecial, or spring-spore, stage on certain wild flowers belonging to the buttercup family.

The rust pustules on the plum leaf represent the summer, or red-rust, spore stage (urediniospores). These, unlike the apple-rust spores, are able to reinfect the plum time and again during the summer. Later in the season the urediniospores are replaced in the pustules by black spores (teliospores) which live over winter and in the spring infect the wild flowers mentioned above. The spores from the wild flowers are carried to the plum leaves, especially to wild plums in the neighborhood, and here start the rust again.

The rust on the plum leaves develops quickly, and as soon as the pustules of reddish brown spores are produced, other leaves may be infected by these spores. This may be repeated thruout the summer. In addition, it has been determined that these red-rust spores are able to live over winter and may reinfect the plum in the spring without passing to the wild flowers. Thus the stage on the wild flowers is not essential for the continued propagation of the rust.

Control.—The rust is seldom serious enough in this section of the country to warrant special control measures. If it should appear in an orchard, spraying with Bordeaux during the latter part of the summer will probably hold it in check.

LEAF SPOT OR SHOT HOLE

Loss from Leaf Spot.—On plums, as on cherries, leaf spot may cause almost complete defoliation by the first of August. This impairs the vitality of the tree to a marked extent and in nursery stock may result in an almost worthless tree.

Susceptibility of Different Varieties.—There is a marked difference in the susceptibility of different varieties of plums to this disease. Japanese varieties are almost immune while those of the European group are very susceptible.

Symptoms.—The symptoms differ from those on cherry in that the lesions are more regular and definite in outline and the yellowing of the leaves is not so pronounced. The diseased tissues in the spots soon fall out, giving the leaf a shot-hole effect. This does not

commonly occur in the cherry leaf spot. The other symptoms, including defoliation and the appearance of a white growth on the under side of the spots, are similar to those of the cherry leaf spot.

Cause.—While the causative fungus is a different species of the genus Coccomyces from the one causing cherry leaf spot, the life history and methods of control are the same. (For further details see page 110.)

PLUM POCKETS

A disease similar in many respects to peach leaf curl occasionally occurs in plum orchards and may cause serious loss. This disease, known as plum pockets, or "bladders," is more commonly found on wild species of plums than on cultivated varieties.

Symptoms.—The fruit, when less than half grown, is seen to be "off color" or, frequently, decidedly reddish in color. As these diseased plums develop they become wrinkled and the surface takes on a fine velvety gray appearance. No stones, or only imperfect ones, are developed and the interior is spongy and somewhat dry. The fruit is strikingly deformed, often being elongated and slightly curved as well as enormously increased in size. It later turns black and the interior dries up so that the plums rattle when shaken. This characteristic has given rise to the common name "bladders."

The leaves are also distorted, the condition resembling peach leaf curl in many respects. Frequently tips of branches are so seriously diseased as to be killed before June.

Cause.—This disease is due to a fungous parasite, *Exoascus Pruni,* a near relative of the Exoascus which causes peach leaf curl.

The organism hibernates in the ends of the twigs and in the spring grows out into the developing flower, where it enters the ovary and feeds upon the tender tissue. It stimulates these growing tissues to produce the abnormal-shaped fruit and inhibits the formation of the seed, or if this is formed it is of a rudimentary character. On the surface of the plum numerous asci are later produced. These are not inclosed but are exposed directly to the air. The ascospores are discharged and probably cause further infection, altho this fact has not been definitely established. The fungus continues to grow in the newly formed twigs and causes these to become deformed. It also develops on the under surfaces of the leaves and causes distortions similar to peach leaf curl.

Control.—Plum pocket can be controlled by proper spraying, but sprays should be used only when accompanied by careful cutting-out operations. It is rarely necessary to apply sprays for this disease alone. In case the disease becomes prevalent in an orchard, the regular spray schedule given on page 113 should be followed.

In cutting out, diseased twigs should be cut back some distance and removed from the orchard. If the disease becomes established in an

orchard the affected trees should be carefully watched and the diseased plums and twigs removed in the spring before the spores of the fungus are developed.

PLUM DISEASES OF MINOR IMPORTANCE

FIRE BLIGHT, caused by the same organism as the fire blight of apple, pear, and quince, also occasionally occurs on the plum. It has not caused serious trouble in Illinois.

SILVER LEAF, caused by a fungus, *Stereum purpureum,* has attracted a great deal of attention in England and Canada but has not been observed in this state. It is also found on the apple, peach, pear, cherry, almond, and other fruit and forest trees, as well as on some bush fruits, such as the currant and gooseberry. The disease is evident on the leaves only, altho the fungus is located in the trunk and larger limbs. The leaves are normal in size but take on a gray or dull silver appearance. The fruiting body of the fungus appears only upon the dead branches. There is no successful method of control, but cutting out all infected branches and burning all dead wood in the orchard aids in checking the spread of the malady.

CROWN GALL occasionally attacks the plum but is seldom serious enough to do a great amount of damage. (See apple, page 57, and raspberry, page 122.)

YELLOWS, ROSETTE, AND LITTLE PLUM are diseases less frequently seen on the plum than are the corresponding diseases on the peach. The symptoms are much the same. The causes of these diseases are unknown. (See peach, page 98.)

PLUM SCAB is caused by the same fungus as the scab of peach and has similar symptoms and life history. It is much less common but sometimes seriously mars the DeSoto variety. (See peach, page 93.)

WILT, caused by a fungus, *Lasiodiplodia Triflorae,* is considered a serious disease in southern plum orchards. It resembles fire blight in that it causes a rather sudden wilting of the branches. It is a wound parasite and is frequently introduced by borers and other insects. Control measures have not been fully developed.

CHERRY DISEASES

BROWN ROT

Loss from Brown Rot.—Brown rot is without doubt the most destructive disease of cherries. During damp, warm, early summers the disease frequently starts in the fruit on the trees and causes serious rotting, especially if the cherries are allowed to become ripe (Fig. 41).

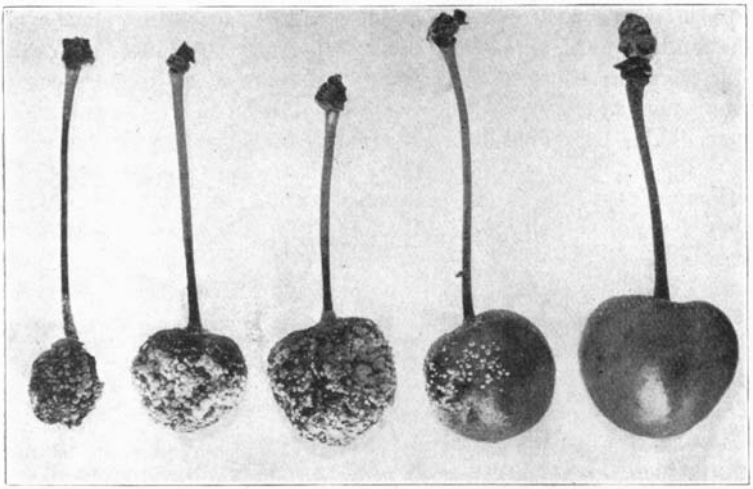

FIG. 44.—BROWN ROT OF CHERRIES SHOWING DIFFERENT STAGES (After Clinton)

The greatest loss, however, is undoubtedly in shipping and on the market. Occasionally the disease attacks the blossoms, causing a blight as described under plum, page 102. It may also attack young twigs causing a twig blight.

Susceptibility of Different Varieties.—There is some difference in varietal susceptibility among cherries but all are more or less seriously attacked provided the weather is favorable. The sweet cherry suffers more than the sour and this explains in part why there has been so little complaint in regard to rot in Illinois.

For a discussion of the *symptoms* and *cause* of brown rot, see under peach, page 87 and plum, page 100. For methods of *control*, see spray schedule, page 113.

POWDERY MILDEW

Loss from Powdery Mildew.—Cherry trees in the nursery sometimes become stunted from the attack of a surface mildew. Older trees suffer to a certain extent, but the disease as a whole is less destructive than the cherry leaf spot. Badly affected leaves do not function properly and the twigs when attacked are stunted.

The disease is more serious on sour cherries than on sweet varieties. The mahaleb cherry is especially free from mildew. The same disease occurs on apple, peach, plum, quince, and other fruits.

Origin of the Disease.—The disease has been known since 1800, when it was described in France. It was probably introduced into this country early in the history of cherry growing thru the importation of stock from abroad.

Symptoms.—In June the white, powdery spots may be observed on the under surfaces of the leaves, especially at the tips of sprouts arising from the roots of the trees. The spots soon become so numerous and large as to form a more or less solid mat over the entire lower surface. The leaves curl inward exposing silvery gray under surfaces. The twigs also are covered with the grayish white powdery growth, and the ends of the branches appear stunted and shortened between the nodes. The affected leaves fall earlier in the season than those unattacked. In August and September, numerous small black dots may be seen scattered over the surfaces of the diseased leaves.

Cause.—The fungus causing the disease is called *Podosphaera Oxyacanthae.* It is a powdery, or surface mildew, and, as its name indicates, grows superficially.

The white masses seen on the under surface of the leaf are composed in part of the superficial mycelium and in part of the white conidia which are produced on club-shaped conidiophores over the surface of the mycelium. These conidia are carried by the wind to developing leaves and twigs where they produce new infections.

The best development of this fungus is during dry, warm weather, a peculiarity common to most surface mildews. Later in the season perithecia, the small black dots mentioned above, are developed among the mycelial threads and asci containing the winter spores or ascospores are formed in these. These ascospores serve to carry the fungus over winter, and in the spring they are released thru the disintegration of the perithecial wall.

Control.—The most effective control of surface mildews in general is thru the application of sulfur dust. Dusting machines of types for all purposes are now on the market. Dusting may be begun with the first appearance of the disease, since this is one of the few fungi which can be killed after infection. This is because of its superficial nature, a property which it has in common with all surface, or powdery, mildews. If necessary, a second application should be made ten days or two weeks later.

Spraying with lime sulfur also controls the disease. If the regular spray schedule given on page 113 is followed it is rarely necessary to apply an extra spray for mildew.

CHERRY LEAF SPOT

Loss from Cherry Leaf Spot.—The most serious disease of cherry foliage in Illinois is leaf spot, or "yellow leaf," as it is frequently called by the orchardist. While not generally regarded as an especially destructive disease, the constant defoliation of the trees which results is undoubtedly a factor in reducing the yield and the vigor of the orchard. Frequently all the leaves on young trees are shed by the

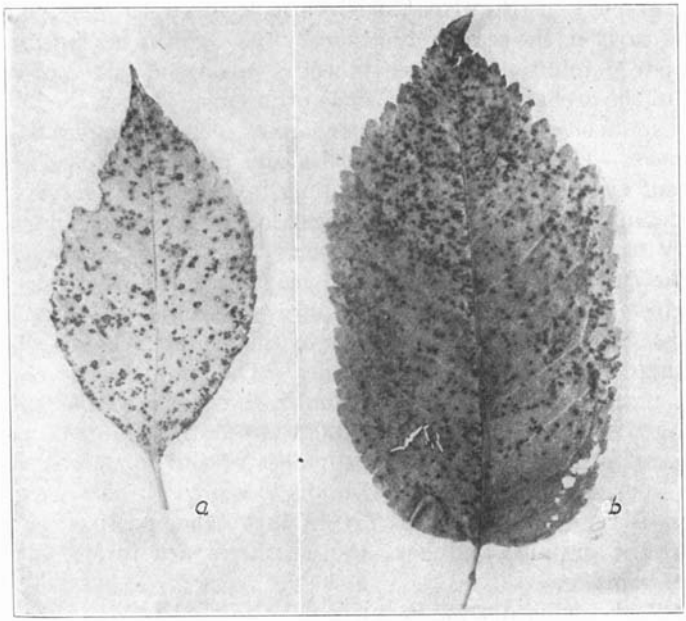

FIG. 45.—CHERRY LEAF SPOT: (a) ON SOUR CHERRY (THE LIGHT AREA IS PALE YELLOW); (b) ON SWEET CHERRY

middle of the summer, especially following a damp, rainy, cloudy spring. Leaf spot is more serious on young trees than on old ones, and is especially destructive in nurseries. Frequently large blocks of nursery stock have to be discarded or sold as inferior on account of the weakened vitality of the trees.

Distribution.—So far as known, this disease is present thruout the cherry-growing section of the United States. It occurs on wild species of cherries and plums and among cultivated cherries on the mahaleb, sweet, and sour cherries, as well as on the cultivated plums.

Symptoms.—During the latter part of May and the first part of June minute purple spots appear in great numbers over the upper surfaces of the leaves, especially on any young sprouts that may be present in the orchard or upon the young trees in the nursery rows. These spots enlarge slightly but remain quite small when the infection is heavy and the spots numerous (Fig. 45, b). The outline of the lesion is usually not well defined in its early stages and is irregular or angular in many cases. Later the area in the center of the spot may die and fall out, giving a shot-hole effect.

On the under surfaces of the leaves following heavy dews or rains, there may be observed a white mildew-like growth. Many of the leaves turn yellow before falling, thus giving rise to the name "yellow leaf" (Fig. 45, a). Frequently there is an area about the spots which re-

mains green, and this gives the leaf a mottled appearance. The leaves fall off early in the season, and thereby the vigor of the tree is reduced. Complete defoliation frequently occurs in nursery stock or on young trees in the orchard. There is some difference between the appearance of the spots on sweet and on sour cherries (compare a and b, Fig. 45).

Cause.—The leaf spot of cherries and plums is caused by several different species of fungi all belonging to the genus *Coccomyces.*[1] In the present account they will be regarded as the same, since their life history is similar regardless of species.

The fungus winters on the old leaves under the trees. It forms a perfect, or ascospore, stage, in an apothecium, and the ascospores are shot upward in the spring onto the young foliage, where they germinate and infect the leaf tissues. The spots are developed as a result of the growth of the mycelium in the tissues of the leaf. Spore-bearing structures similar to pycnidia but more open, and called acervuli, are formed on the under surfaces of the spots, and numerous white spores are produced which may reinfect other leaves. This process is repeated as long as favorable weather persists. The leaves fall to the ground, and here the apothecia are formed during the fall and spring.

Control.—This disease is fairly easy to control, at least to such a degree as to insure the continued vitality of the tree. It has been found that lime sulfur (1-40) with lead arsenate added and applied just after the petals fall and again about two weeks later, will control the disease. The addition of lead arsenate seems to increase the fungicidal value of the spray. Iron sulfate, 1¼ pounds to 50 gallons of spray mixture, decreases the amount of injury to the foliage.

Bordeaux mixture applied at the dates given above also successfully controls the disease, but the lime-sulfur solution is preferable in that it is usually more available.

Since the fungus winters over on the old leaves in the orchard, clean cultivation started early in the spring will evidently tend to reduce the chances of infection.

More frequent sprayings are necessary in the nursery than in the orchard. Spraying should begin when the trees are only a few inches high and should continue until the middle of July at intervals of two weeks.

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[1]Higgins (Amer. Jour. Bot., 1 (1914), 145-173) separates the species on stone fruits as follows: *Coccomyces hiemalis* on *Prunus avium, P. Cerasus,* and *P. pennsylvanica; Coccomyces prunophorae* on plums (*Prunus Americana, P. domestica,* and *P. insititia*); *Coccomyces Lutescens* on *Prunus serotina, P. virginiana,* and *P. mahaleb.*

SPRAY SCHEDULE FOR TREE FRUITS[1]

	DORMANT SPRAY	FIRST SUMMER	SECOND SUMMER	THIRD SUMMER	FOURTH SUMMER	ADDITIONAL SPRAYS
Apple	Lime sulfur, 5½-50[2]. Apply when trees are dormant, either in the spring or fall	"Cluster-bud spray" Lime sulfur, 1¼-50. Arsenate of lead (dry), 1-50[3]. Apply just before blossoms open	"Calyx spray" Spray mixture same as first summer. Apply just as petals fall	Spray mixture same as second summer. Begin spraying in time to complete application by tenth day after second summer spray	Spray mixture same as third summer. Begin spraying in time to complete application three weeks after fall of blossoms	1. Where blotch is present, apply lime sulfur or Bordeaux (3-4-50)[1] five weeks after fall of blossoms. 2. When bitter rot is present, apply Bordeaux (3-4-50)[1] beginning about July 1 and continuing until four applications are made at ten-day intervals
Quince and Pear	As for apples. Usually not necessary for Kieffer	As for apples	As for apples	As for apples. Usually not necessary for Kieffer		
Peach	As for apples	Arsenate of lead, 1-50.[3] Add 2 or 3 pounds of properly slaked lime. Apply ten days after fall of blossoms	Self-boiled lime sulfur, 8-8-50.[1] Arsenate of lead as in first summer. Apply three or four weeks after fall of blossoms	Self-boiled lime sulfur, 8-8-50.[1] Apply four or five weeks before fruit is ripe		If hot, damp weather occurs, keep fruit well coated with self-boiled lime sulfur
Plum	As for apples	Lime sulfur, 1¼-50[2]. Arsenate of lead (dry) 1-50.[3] Apply just before buds open	Spray mixture same as first summer. Apply immediately after fall of blossoms	Spray mixture same as second summer. Apply ten days after fall of blossoms		As for peaches
Cherry	Usually not necessary	As for plums	As for plums	In case of warm, damp weather spray as for plums		

[1]For preparations of spray mixtures, see page 12.

[2]Lime-sulfur mixtures are given in numbers expressing the number of gallons of the commercial lime sulfur used to make 50 gallons of spray mixture, e. g., 5½-50 means that 5½ gallons of the concentrated commercial lime sulfur is to be added to 44½ gallons of water.

[3]One pound of powdered arsenate of lead to 50 gallons of spray mixture or 2 pounds of paste to 50 gallons.

PART III

DISEASES OF SMALL FRUITS

DISEASES OF BRAMBLES

The brambles (raspberries, blackberries, and dewberries) rank second in importance among the small fruits in Illinois. These fruits have most diseases in common and for this reason are treated together. The blackberry has few serious diseases, orange rust and crown gall being the only destructive ones. The raspberry is not only subject to these diseases, but is also severely affected by anthracnose, cane blight, and leaf curl.

ANTHRACNOSE

Loss from Anthracnose.—Anthracnose has entirely eliminated the growing of raspberries in some sections of Illinois, and many growers are compelled to renew their patches after two years of bearing. The effective control of this disease will result in a much greater acreage being planted to raspberries.

Few growers realize the damage done by anthracnose as it does not directly attack the fruit but causes loss indirectly thru weakening the plant. The disease is found on the canes above the ground and on the petioles and blades of the leaves. The cane lesions cause the greatest damage. Weather conditions play an important part in the amount of damage done. If dry weather prevails previous to ripening, the crop is frequently an entire failure because of the drying up of the fruit and often the death of the canes occurs.

In 1908, the loss in Illinois thru anthracnose is estimated to have been over 50 percent of the crop; twenty-five percent of the berry crop is lost annually thru the disease.

Origin and Distribution.—Anthracnose is very generally distributed thruout America, Europe, and Australia. It was reported by Doctor T. J. Burrill as widespread in this state as early as 1882. It is commonly found on wild raspberries and was probably present before the general introduction of commercial varieties.

Susceptibility of Different Varieties.—Both the red and the black raspberry are susceptible to anthracnose altho the disease is more destructive to the black-caps. It is also found on blackberry, loganberry, dewberry, and purple-cane raspberry. In Illinois the blackberry is sometimes severely attacked.

There are no varieties of raspberry known to be entirely immune to the disease. The most susceptible varieties under Illinois conditions are Eureka, Gregg, Erie, Eldorado, Early Harvest, and Mammoth Cluster; the least susceptible are said to be Kansas, Cumberland, and Plum Farmer.

Symptoms.—The disease first appears on young canes in the spring as small, purplish, slightly raised spots. As the canes grow, the spots

enlarge and become lens-shaped or oval, with a slightly raised, purple edge. The center gradually takes on a dull grayish color and later becomes sunken and fissured (Fig. 46). The lesions are often so close together that they form large irregular spots with ill-defined edges. During the early part of the second year the cracks which developed during the previous year are deepened, so that the entire bark and "wood" of the cane underneath the spots are rendered almost functionless. Similar lesions are found on the stems and midribs of the leaves and occasionally on the stems of the berries.

On the leaves, small purple-bordered spots are developed rather late in the season. This disease should not be confused with the septoria leaf spot of the raspberry, which is much more destructive and which appears much earlier in the season.

Cause.—A fungus, *Plectodiscella veneta,* is the cause of this disease.

The fungus winters in the mycelial condition in the one-year-old canes. In the spring, spores are produced in the lesions previously described, and are carried by the rain or other agents to the young shoots which are coming up about the old, diseased canes. These spores alight on the tender surface of the young canes and adhere to them by a sticky substance developed on the spore surface. Here they germinate when weather conditions are favorable, and the germ tube forms a mass of fungous tissue beneath the cuticle of the host. As the lesion develops on the cane, the mycelial tissues thicken and form distinct pustules on the surface which may be seen with the naked eye.

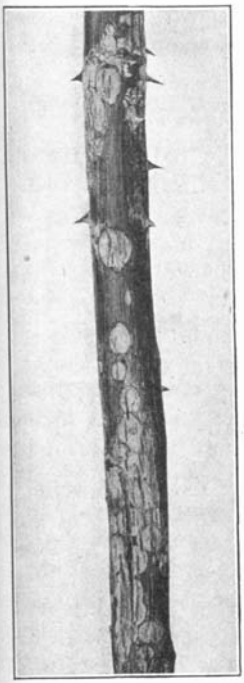

Fig. 46.—Raspberry anthracnose on cane

The fungus also develops ascospores which survive the winter in certain masses of fungous tissue. These are discharged from the stromata in which they are developed and ultimately cause reinfection. This stage is probably rare and is not necessary in the life history of the fungus.

Since the raspberry is propagated by layering and cuttings, and since anthracnose lesions occur to some extent along the entire stem, the disease is easily transferred to new beds on the young plants. Once started in a bed it can of course continue from year to year, passing from the old canes to the new each spring.

Control.—From recent experiments in Michigan, and in this state, it seems possible to control anthracnose by careful and consistent

spraying with lime sulfur. Three applications are recommended as follows:

1. In the spring before growth starts, use lime sulfur diluted at the rate of 2½ gallons in 50.
2. When new shoots are six to eight inches high, use lime sulfur diluted at the rate of 1¼ gallons in 50.
3. Just before the blooming period, use lime sulfur diluted at the rate of 1¼ gallons in 50.

It is important that new plants should be free from anthracnose when a new bed is set. The surest way to control anthracnose in a new patch is to carefully remove all the old stubs before setting the plants. The nurserymen leave these on to facilitate handling the plants, but they are not necessary for propagation and cutting them off entirely will not injure the plants. Only the roots and buds should be left when the plants are set in the rows. The stubs should be cut off and burned before the plants are taken to the field.

Old patches should not be retained too long, as the disease is much harder to control after it has become thoroly established.

It is also very important to practice clean cultivation, since the moisture held by weeds in the row favors the development of the disease.

RASPBERRY LEAF CURL

So far as known, this disease is confined to the red varieties of raspberries. It has not been commonly observed in Illinois, but where it has appeared it has proved to be one of the most serious diseases on account of its mysterious nature and our present inability to control it successfully. This disease is frequently called "yellows" and "Marlboro disease" by growers.

Susceptibility of Different Varieties.—Cuthbert and Marlboro are regarded as the most susceptible, the latter especially so; Golden Queen and Herbert are also moderately susceptible. Early King is reported as quite resistant in Minnesota, while fairly susceptible in Kansas.

Symptoms.—Leaf curl usually appears in a fairly well-defined area in the patch. At a distance the foliage in this area appears lighter, smaller, and sometimes decidedly yellow (Fig. 47). A closer examination reveals the fact that the leaves on some, but not all, of the canes are decidedly different in character from normal leaves. The edges of the leaves turn down and the whole surfaces of the leaves are uneven and folded (Fig. 48), giving an appearance similar to leaf curl of peach. It is this characteristic which gives rise to the common name, leaf curl. Where the leaf arches upward the arched surface looks lighter than the crevices, giving the leaf a mottled appearance which is quite characteristic of the disease. Later in the season the leaves take on a decided yellow or yellowish green cast.

FIG. 47.—RASPBERRY LEAF CURL, SHOWING HEALTHY AND DISEASED PLANTS
(From Hesler and Whetzel's Manual of Fruit Diseases, Macmillan Co.)

The entire bush is different in appearance from the normal plant. The leaves are much smaller and the branches are short and "bushy." The berries ripen from ten days to two weeks before the normal ripening season and are much smaller and lighter in color than the unaffected berries.

Leaf curl should not be confused with other weakened conditions of the raspberry which may have a somewhat similar appearance but rarely the curled character of the leaf and the general bushy appearance of the entire plant.

Cause.—The cause of leaf curl is unknown at the present time. A number of similar diseases of fruits and other economic plants have been investigated for years without establishing a definite cause. The best example is that of peach yellows, which in many respects is similar to raspberry leaf curl. It has been noticed that healthy and diseased canes may appear in the same stool.

Control.—Since no organism has been found associated with the disease, and since the conditions bringing it about are unknown, only general measures of control can be recommended: (1) If the disease appears in a portion of a patch, dig up and destroy the plants in this area. (2) Select well-drained light soil for the site of the patch. (3) Avoid those varieties known to be very susceptible, especially the Cuthbert and Marlboro. The Cuthbert can probably be safely planted on light ground. (4) Secure plants from patches known to be free from leaf curl.

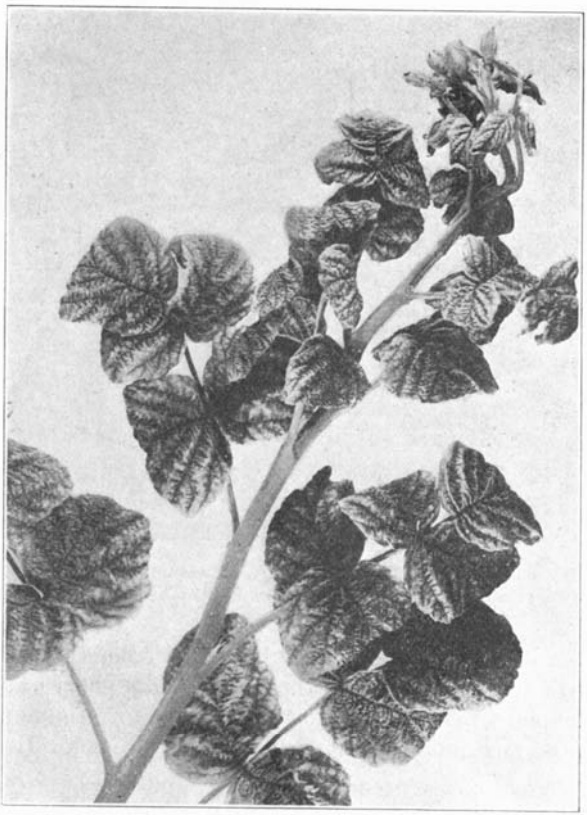

FIG. 48.—RASPBERRY LEAF CURL
(Photographed by C. H. Coons, Michigan Agricultural Experiment Station)

SPUR BLIGHT

While not a well-recognized disease of raspberries in Illinois, spur blight is nevertheless present in most plantations. It is common only on red raspberries and is seldom found on the purple-stemmed varieties. It is not known to occur on the blackberry.

Distribution.—Spur blight has been reported in widely separated regions of the United States and there is little doubt that it is very generally distributed. There is some question regarding its importance in various parts of the country. In Colorado it is considered the most serious disease of red raspberries, while in New York it is thought to be of no importance. It has seldom been observed causing an active blight of the spurs in Illinois.

Symptoms.—The first appearance of the disease is a brown or purplish brown discoloration on the young canes just below the leaf

FIG. 49.—SPUR BLIGHT OF RED RASPBERRY, SHOWING GRAY LESION WITH BLACK PERITHECIA AND CRACKED BARK

FIG. 50.—CANE BLIGHT OF RASPBERRIES, SHOWING PYCNIDIA AND SMOKY AREAS OF EXUDED SPORES

stems. This appears about the middle of July and is observed only on the lower part of the cane. During the remainder of the season the lesion spreads up and down the stem so that the stem is discolored for a distance of several inches above and below the node, or leaf junction (Fig. 49). Usually the bark splits longitudinally and becomes dry and brown. As the lesions become older they turn to a tan-gray color, and consequently the disease is often called the "gray-bark" disease.

In September, small black pimples appear on the surface of some of the lesions (Fig. 49). These are not always found near the center of the diseased area but may be near the outer edge in isolated patches.

Cause.—The disease is caused by a fungus, *Mycosphaerella rubina.* The perfect, or ascospore, stage is developed during the fall and early spring in the little black pustules (Fig. 49). The perithecia remain immature over winter, and the asci and ascospores are formed early in the spring. They are discharged in the early part of May and, falling on the young shoots, start a new infection. The imper-

fect stage (a Phoma[1]) is not regarded as important in the life history of the fungus.

Control.—Unless the disease assumes more importance in this state, it is not considered an economical proposition to attempt its control. In Colorado, success has been obtained by the use of Bordeaux mixture (3-2-50) to which two pounds of rosin-fish-oil soap is added. Applications should be made to the *young canes* only, special care being taken to cover the parts near the ground. The first spray should be applied when the plants are from eight to twelve inches high. Subsequent sprays should be about two weeks apart, four sprays in all being applied.

CANE BLIGHT

This disease has been found in a number of localities in Illinois and is rather widely distributed over the state. Little is known concerning its destructiveness so far as Illinois conditions are concerned since no observations were made prior to the season of 1918; but, because it is found here and in view of its destructiveness in the eastern states, a description in this circular is warranted. It is quite possible that damage attributed by growers to anthracnose may have been caused in part by cane blight.

Cane blight was first observed about 1899, in the Hudson valley in New York. Since then it has been found in several other states, indicating that it had probably been present in America previous to that time.

Loss from Cane Blight.—The amount of damage varies greatly with different years. A warm, wet summer, followed the next year by a wet spring with a dry period during ripening, is most favorable for the development and destructive action of the disease. It has been noticed that relatively little damage results when there is plenty of rainfall during the ripening period. The disease is more destructive in old plantations than in new ones. In New York the loss of from one-third to two-thirds of the crop is commonly reported during seasons favorable for the development of the disease. It is doubtful if such loss ever occurs in this state.

Susceptibility of Different Varieties.—So far as known, cane blight occurs only on red and black raspberries. It has been observed on the wild red raspberry, *Rubus strigosus,* in New York. The Cuthbert variety is especially susceptible, while the Columbian is regarded as very resistant. Marlboro, Gregg, Kansas, Cumberland, and Pride of Geneva are also susceptible.

Symptoms.—As the name indicates, the disease occurs on the canes. The loss is due to wilting of one or more branches. Usually this sud-

[1]Letter of A. G. Newhall, University of Minnesota, May 18, 1919.

den wilting is the first observed symptom. This takes place generally about the time the berries are beginning to ripen, especially if the weather is dry during this period. If the cane below the wilted branch is observed, a diseased area will be found. The lesions at this time are usually several inches in length. The bark is lighter in color and the wood beneath is dead and discolored, while above and below the diseased area the cane may appear quite healthy. On the surface of the lesions, small black dots may be observed often surrounded by smoke-colored smudges (Fig. 50).

The disease frequently starts at the surface of the pruning wound and works downward, killing the branches as it advances. Sometimes it appears first near the surface of the ground and causes the wilting of the whole cane, resembling the damage done by anthracnose.

Cause.—Cane blight is caused by a fungus, *Leptosphaeria coniothyrium*. On the cane, pycnidia are developed in which are produced enormous numbers of brown spores. These are exuded in such quantities as to form the smutty discoloration described. These pycnidia, formed on the fruiting canes, produce spores thruout the summer. In the meantime the new canes are growing up among the fruiting canes, and when these are headed back the fungus is given a chance to infect them at the wounded ends. Infection at other points on the new canes may occur during the summer, but it usually appears only where the canes are wounded or injured by insect puncture.

The fungus winters in the mycelial condition on the new canes as well as on the old fruiting ones. On the diseased area of the fruiting canes the fungus develops perithecia during the fall, and in the spring ascospores are formed in these. In addition, the pycnospores live over winter or are formed in the old pycnidia in the spring.

The fungus may live on the old canes for at least four years after the canes have died. It is thus evident that there are numerous sources of infection in the spring and summer. The pycnospores or ascospores may be carried by rain or mist or by insects to the new growth and here cause infection. Insects, such as the tree cricket, evidently play an important part in disseminating the spores. So far as known, the fungus gains entrance only thru wounds on the canes, but these wounds are so common that there are usually plenty of chances for infection. It is also known that the berries may become infected and the fungus may grow down the pedicel and into the fruiting branches.

The fungus causing cane blight of raspberries has been found to produce serious cankers on apple trees in Kansas and a fruit spot of apple in New York.

Control.—Owing to the fact that the fungus can winter on old and new canes in the mycelial stage and live for several years on the dead canes, methods of control have not met with much success. Fortunately, under ordinary conditions, the disease does little damage.

Preventative measures consist in (1) securing plants free from the disease, (2) cutting out and burning old canes as soon as possible after the fruit is harvested, and (3) avoiding wounding the new canes in so far as possible.

Spraying has not proved entirely successful, and it is doubtful whether it pays to apply sprays for this disease alone.

Raspberries should not be planted among apple trees on account of the relationship of cane blight to canker and fruit spot.

CROWN GALL

Loss from Crown Gall.—There is always a serious loss from crown gall on brambles both in the nursery and in the field, nurserymen frequently having to discard from ten to fifty percent of their plants. The presence of the crown-gall organism in the soil renders it unfit for many other nursery crops. It has been the common experience of nurserymen that when infected raspberries are followed by peach trees, the crown gall is very serious on the peach stock.

FIG. 51.—CROWN GALL OF RASPBERRY

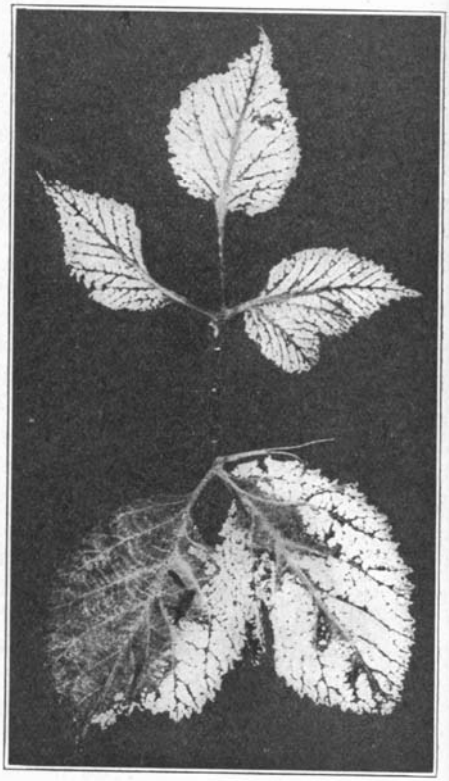

FIG. 52.—ORANGE RUST OF BLACKBERRY. LIGHT AREAS ARE A DEEP ORANGE COLOR

Susceptibility of Different Varieties.—There appears to be little difference in the relative susceptibility of the varieties of raspberries to crown gall, except that red raspberries as a group are especially susceptible.

Symptoms and Cause.—While called "crown" gall, and most frequently occurring near the surface of the ground, the galls are often found on all the roots and at some distance from the stalk.

A discussion of the cause of crown gall is given under crown gall of apple, page 56. The appearance of the galls on raspberry is sufficiently illustrated by Fig. 51. A partial list of plants subject to this disease is given on page 56.

Control.—The control of crown gall on raspberries depends almost entirely upon crop rotation. In so far as possible, in the nursery, raspberries should not follow raspberries or other crops upon which crown gall has been found. A number of field crops should follow a raspberry planting before the ground is again used for raspberries.

In sending out stock the nurseryman should be very careful to discard all suspicious plants, and the purchaser should carefully examine the plants before putting them into the ground. Every plant showing unusual swellings or knobs on the roots should be discarded or returned to the nurseryman to be replaced.

Raspberries should not be planted among peach trees.

ORANGE RUST

Orange rust has been known in Illinois since 1850 and was probably present on the wild blackberries before that time. In this state it is primarily a disease of the blackberry, seldom appearing on the cultivated raspberry. It has attracted much attention on the part of amateur berry growers on account of its striking color in the spring.

Loss from Orange Rust.—While found most commonly on wild species, orange rust causes serious losses in cultivated patches. The plant once infected never recovers, the rust appearing year after year. The leaves are the only part attacked, but they are usually so heavily infected as to be of little use to the plant.

Susceptibility of Different Varieties.—The Snyder blackberry is regarded as the most resistant variety in this state. Other varieties seem to differ little in their relative susceptibility.

Symptoms.—About the latter part of April or the first of May, small yellow dots may be observed scattered over both surfaces of the leaf. About two or three weeks later, light-colored patches develop on the under surface of the leaf upon which the yellow dots were produced. A few days later the epidermis is ruptured, exposing large orange-red patches on the lower surface of the leaf (Fig. 52).

Cause.—The orange rust of blackberry is caused by a rust fungus called *Gymnoconia interstitialis.*

Unlike the cedar rust this fungus does not have a spore stage on an alternate host, but has its entire development on the blackberry. The yellow dots first developed are small chambers, called spermogonia, in which very minute, functionless spores, *spermatia,* are produced. The masses of orange-colored spores on the under surface of the leaf are the aeciospores. These spores correspond to both the aeciospores on the apple leaf and the teliospores in the horns of the cedar apple. They may directly infect the plant or, upon germination, produce a short promycel on which sporidia are formed.[1] These sporidia are then blown about and may infect other plants.

The fungus winters in the mycelial stage in the roots and stems of old plants. In the spring it grows up in the pith of the developing cane and out into the leaves, where it produces the spore forms described. The fungus is therefore perennial, and on this account when once in a plant it cannot be eradicated.

Control.—The only effective method of combating this disease is to dig up the plants and destroy them. Since wild blackberries are especially subject to orange rust all diseased plants in the neighborhood of the patch should be destroyed. Resistant varieties, such as Snyder, should be planted.

LEAF SPOT

Altho one of the commonest diseases of raspberry and blackberry, leaf spot is not generally regarded as destructive. The disease seems to be generally prevalent wherever brambles are grown, and all varieties are susceptible. Red varieties of raspberries suffer most severely in Illinois, and in favorable years partial defoliation may result.

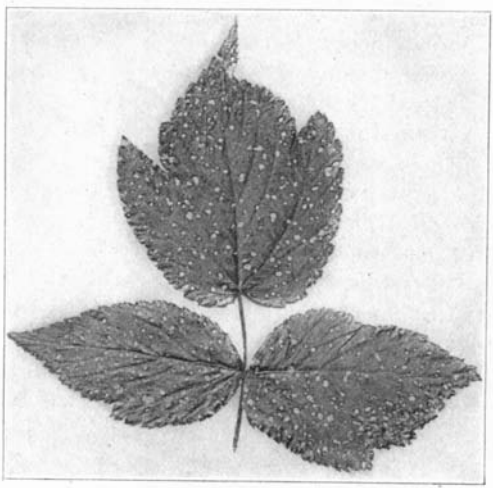

Fig. 53.—Septoria leaf spot of raspberry

Symptoms.—Minute purple dots appear on the leaves about the first of June or later, according to weather conditions. On raspberry leaves these spots soon turn to an ashen gray in the center but remain small, rarely exceeding one-fourth inch in diameter (Fig. 53). The spots on blackberry leaves

[1]There is a question as to whether the life cycle varies as here described or whether the difference in behavior is caused by the presence of two species, one a southern, the other a northern form.

vary somewhat in character from those on raspberry; the edge of the spot shows a zone of reddish brown and the center is light brown or tan (Plate I, e). On some varieties of raspberries the lesions more nearly resemble those on the blackberry. In the center of the larger spots minute black dots may usually be seen.

The disease appears also on the canes of raspberries but is entirely superficial in nature and probably does no damage. In the fall, minute black dots appear on the gray or light tan surface of the bark. In the spring these are especially evident on the old canes and on the ends of branches which have died the previous season.

Cause.—The causal fungus is *Mycosphaerella Rubi.* It is more commonly known under the old name of *Septoria Rubi,* which was applied before the perfect stage was known.

The pycnidia, the black dots mentioned, are filled with many long slender spores which ooze out during damp weather. These are washed over the surfaces of the neighboring leaves, and probably carried by mist showers to other portions of the patch. Here new infections take place.

The fungus winters on the leaves and produces perithecia which develop ascospores in the spring. The pycnidia on the canes produce numerous pycnospores in the spring and these, no doubt, also bring about infection of the new foliage and canes.[1]

Control.—Few attempts to control this disease are recorded. In connection with other spraying experiments, however, it has been demonstrated that it is possible to check the disease to some extent, either with Bordeaux mixture or lime sulfur. The Bordeaux mixture should be used as for spur blight; stronger solutions may cause injury. As a rule the loss from this disease is probably not great enough to justify control measures except in so far as the general condition of the patch is improved by regular spraying.

CURRANT AND GOOSEBERRY DISEASES

Currants and gooseberries are fruits of minor importance in Illinois from a commercial standpoint, but are planted extensively for home consumption. These fruits may assume greater commercial im-

[1]The fungus on the canes has been known in literature as *Rhabdospora Rubi* Fckl. In 1910, Potebnia (Ann. Mycol., 8 (1910), 42-92) suggested the relationship of the leaf and stem Septorias on the basis of similarity of cultural characters. The proof of the identity of the two fungi together with the discovery of the perfect stage is to be credited to Doctor Roark, according to the following extract from a letter to the author from G. W. Keitt, of Wisconsin:

"Doctor Eugene Roark has discovered the perfect stage of *S. Rubi* and has described it as *Mycosphaerella Rubi* in his doctor's thesis, which unhappily is still unpublished, owing to his death.

"Doctor Roark found by morphological and cross-inoculation studies that the fungus on the canes [*Rhabdospora Rubi*] is identical with that on the leaves."

portance within a few years on account of the fact that they are being destroyed in other states in great numbers because of their relation to the white-pine blister rust. Since few pines are grown in this state, there is no reason why these fruits should not be grown here to supply the increased needs of states having large pine forests which must be protected.

The diseases of gooseberries and currants are so similar in nature that they will not be treated separately. Unless otherwise stated the descriptions apply to both these fruits.

The leaf-spot diseases are most serious in this state on account of the defoliation which results every year. Few seasons pass without almost entire defoliation of the gooseberry bushes by the first of August, and frequently the loss of foliage before this date is so great as seriously to impair the vitality of the bushes. The gooseberry mildew prevents the successful growing of some English gooseberries, which are much superior in quality to the American varieties, especially as ripe fruit.

ANTHRACNOSE

There are two leaf spots of currants and gooseberries which are often confused, the anthracnose and the Mycosphaerella leaf spot. These two diseases are responsible for most of the loss of foliage and are frequently present on the leaves at the same time.

Susceptibility of Different Varieties.—Anthracnose occurs both on gooseberry and on currant. Black currants are rarely seriously affected. Varietal resistance is marked, according to observations of V. B. Stewart in New York. White Grape, Fay, Victoria, and Wilder varieties of currants, and Smith, Industry, Houghton, and Whitesmith among the gooseberries are quite susceptible, while Moore, Ruby, and Perfection currants and Downing and Pearl gooseberries are less seriously affected.

Symptoms.—The disease affects the leaves, fruit, fruit stalks, and canes.

On the older leaves, numerous dark brown or reddish brown spots less than one-eighth inch in diameter appear rather early in the season. These are especially apparent on the upper surface. The center does not show a dead area as in the case of the Mycosphaerella spot. After the lesion has enlarged somewhat, a single black dot appears in the center. The leaves turn yellow or are decidedly mottled in appearance and usually fall quite early in the season.

While not serious *on the canes,* the disease often causes minute black spots on the current year's growth.

The fruit stems are also frequently affected, impairing both the size and quality of the fruit.

On the fruit the disease is rarely of any importance but may cause small black spots when prevalent.

Cause.—Anthracnose is caused by a fungus, *Pseudopeziza Ribis.* In the center of each spot on the leaf there is developed a single fruiting body called an acervulus. In this structure the conidia, or summer spores, are produced in great numbers and thruout the summer are washed over the leaf surfaces, causing new infections. Finally, the leaves are so seriously diseased that they fall.

The fungus may live over winter in these fallen leaves in the conidial stage, or the mycelium in the leaf may produce an apothecium in which asci containing ascospores are formed. These ascospores may also serve as a means of infection on the young growth in the spring. It is known that the fungus develops spots on the young canes, and it is probable that the mycelium lives over in these spots and produces conidia in the spring. This fact has not been established, however. The ascospores develop very early in the spring and are carried to the young leaves as they appear.

Control.—Anthracnose can be controlled by the application of lime sulfur (1-50) at regular intervals. The first application should be made as the leaf clusters appear, and subsequent applications every two weeks until the latter part of July or the first of August. Dusting with finely ground sulfur has been found effective. Use 90 parts fine sulfur and 10 parts arsenate of lead.

MYCOSPHAERELLA LEAF SPOT

This leaf spot is more generally known as the Septoria spot. It might appropriately be called the "large" leaf spot to distinguish it from anthracnose. In Illinois this disease is more commonly found on currants than on gooseberries and is especially troublesome on the black currant and on the flowering currant (*Ribes odoratum*), which is extensively grown for ornamental purposes. The gooseberry also suffers but not to the same extent as the currant. The early defoliation of these bush fruits each season is probably due to a combination of Mycosphaerella leaf spot and anthracnose.

Symptoms.—In addition to being larger, the Mycosphaerella spot is distinguished from anthracnose by the fact that there is a definite dead, brown area in the center, on the surface of which may be seen numerous black dots (Fig. 54, c). The area outside the dead, light brown center is at first dark reddish brown and gradually merges into the normal green of the leaf. The spots are circular or somewhat irregular in outline and vary in size from one-eighth to three-eighths inch (Fig. 54, a, b, c). When abundant, several of them may merge. The leaf turns yellow and falls off early in the season. On the flowering currant the spots are larger, more nearly circular in outline, and the black dots are more numerous (Fig. 54, c).

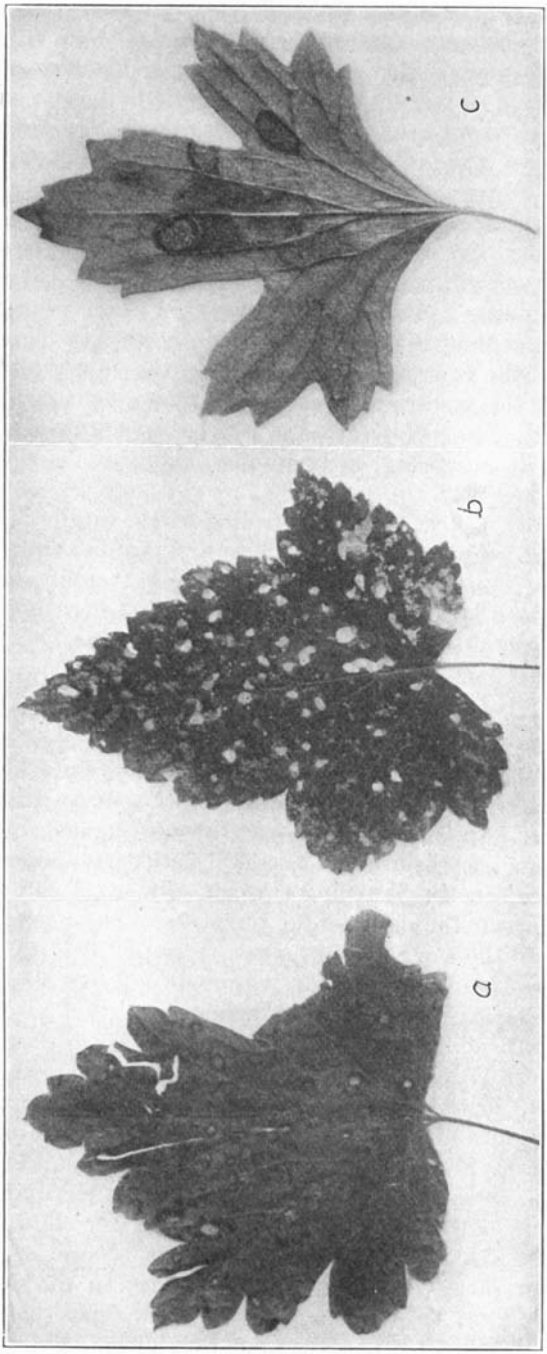

FIG. 54.—MYCOSPHAERELLA LEAF SPOT OF CURRANT AND GOOSEBERRY: (a) ON GOOSEBERRY; (b) ON BLACK CURRANT; (c) ON FLOWERING CURRANT, SHOWING PYCNIDIA

The large size of the spots and the pycnidia in the central, brown, dead area sharply distinguish this disease from the anthracnose spot.

Cause.—This disease is caused by a fungus, *Mycosphaerella Grossulariae,* formerly known only in the imperfect stage as *Septoria Ribis.*

The fungus lives over winter on the fallen leaves as does the anthracnose fungus. Here, partly in the fall and partly in the following spring, it develops perithecia, in which ascospores are formed. These are discharged with some force and carried to the unfolding leaves, where they produce the first infections. Pycnidia develop in these spots. The pycnospores ooze out of them and are carried to other leaves to cause new infections.

The spots usually begin to appear about the middle of June, or earlier, in southern Illinois, and leaf fall takes place from the first of July thruout the summer.

Control.—The measures followed in the control of anthracnose are effective in the control of this leaf spot.

ANGULAR LEAF SPOT[1]

The foliage of currants is often observed to be spotted with numerous brown- or gray-centered dead areas. This condition is especially noticeable during the latter part of the summer. Angular leaf spot is more common during some seasons than others and at times causes serious loss of leaf surface. It does not appear to cause defoliation as does the Mycosphaerella leaf spot but it kills larger areas of leaf surface. It has never been observed on gooseberries in Illinois.

Fig. 55.—Angular leaf spot of currant

Symptoms.—The lesions appear during July as small dark red or reddish brown spots scattered over the surface of the leaf. They are usually circular or slightly irregular in outline with a light green zone around the dead center (Fig. 55). The spots are not sharply outlined as in the case of the Mycosphaerella leaf spot. The lesions enlarge during the course of the summer and often reach a diameter of two-fifths of an inch. The center becomes gray and the outline of the entire lesion more irregular or angular (Fig. 55). When the spot becomes quite large the central dead area often ruptures so that large irregular holes result. The diseased area is much larger than that resulting from anthracnose.

[1]Unfortunately this common name is not descriptive of the spot; however, it is used here on account of its general acceptance by plant pathologists.

Cause.—The angular leaf spot of currants is produced by the fungus *Cercospora angulata.*

The spores of this fungus are borne in numerous small tufts on the upper and lower surfaces of the lesions. These are sometimes visible to the naked eye as a very fine, fuzzy growth on the gray centers of the older spots. Pycnidia, so evident on the Mycosphaerella spot, are entirely lacking. Spores produced on these tufts are easily broken off and are carried to other leaves by wind and rain. Nothing is known concerning the wintering of the fungus altho there is little question but that the spores produced during one season may live over to the next.

Control.—The disease, together with other leaf spots, has been controlled by the application of Bordeaux mixture every two weeks from the latter part of May until the middle of July.

EUROPEAN RUST

On account of its disastrous effect on white pine, this disease is most commonly known as the "white pine blister rust." It was imported on white pine seedlings from Europe about 1909 and has since spread over the eastern pine-growing states and has been found as far west as the Mississippi river in the northern states. Every effort is being made to check the disease, and nurserymen and fruit growers in general should cooperate in this movement despite the expense involved.

The currant and gooseberry rust here described is not known to occur in Illinois. It is important, however, that growers of these fruits should realize the danger of growing white pines in the neighborhood of currant or gooseberry plantations, and if this is attempted, familiarity with the symptoms of the disease, both on the bushes and on the pine, is very essential. The nurserymen in the state are especially warned against the danger of growing seedling pines of the five-needle group in the same nursery plantation with these fruits. The disease is never likely to become of any importance in Illinois except in the neighborhood of nurseries.

Symptoms.—On the lower surfaces of the leaves of currants and gooseberries the disease appears as small, rusty red pustules, about one-eighth inch across. These may appear as early as June or at any time later in the season. The leaf tissue at the point of attack does not die, but if the infection is severe the leaf may fall prematurely. Later in the season short, black threads are produced on the lower surfaces of the leaves.

On the pine there is usually a spindle-shaped swelling where the disease is developing. These enlargements are usually on wood at least three years old. In April or early May shortly after the swelling is first noticeable, small blister-like pustules appear on the surface of

the swollen area. These break open, exuding drops of clear fluid. Later orange-colored masses are pushed up thru the bark. These masses later disappear, leaving an empty pit in the surface of the swelling.

The rusty pustules on the under surfaces of the leaves of the currant or gooseberry and the swollen areas on the pines, with orange-colored masses in May, are the characteristics which should be watched for by growers.

Cause.—This disease is caused by *Cronartium ribicola,* a true rust fungus.

One stage of the rust, that corresponding to the cedar rust on the apple leaves and fruit, occurs on the white pine and several other five-needle pines. Unlike the rust on apple, however, the mycelium of this fungus lives over winter in the pine tissues. In the spring it develops the orange-colored aeciospores described above. They are carried to currants and gooseberries in the neighborhood and infect these, causing the rusty spore masses, the urediniospores, to develop on the under surfaces of the leaves. While the aeciospores from the pine cannot reinfect the pine, but must pass to the currant or gooseberry, the urediniospores can continue to reinfect the fruits thruout the year.

During the latter part of the summer, however, there are produced on the under surfaces of the leaves another type of spores, the teliospores, which are not able to reinfect the fruits but are blown or carried to the vicinity of pines in the neighborhood. These teliospores germinate wherever they alight, when sufficient moisture is present. They produce a number of short stalks on each of which another type of spore is produced, called a sporidium. This spore, if it alights on the pine, will infect it, while if no pines are in the neighborhood, it soon dies.

The infection on pine takes place during the latter part of the summer, and the fungus winters in the tissue of the pine. It usually develops here for several years before the aecia described above are produced. During this time the mycelium, by its activities, causes abnormal cell multiplication in the host and brings about the swollen condition. When the aecia are finally produced, the aeciospores reinfect the currant or gooseberry.

Control.—Under Illinois conditions the control of this disease is largely a matter of education. There is no reason why young pines should be grown in close proximity to currant and gooseberry bushes, and since it is known that the spores are not carried more than a few hundred yards, there should be no difficulty in keeping these hosts apart. Where white pine seedlings are grown, great care should be exercised in eliminating all species of Ribes from the neighborhood. Where gooseberries and currants are grown on a large scale, the same

care should be exercised in preventing the planting of large numbers of pines within a quarter of a mile of the patches.

Illinois is not a pine-growing state and, where possible, other trees should be planted for ornamental purposes. If evergreens are desired, species known to be immune to the blister rust should be planted.

POWDERY MILDEW

This malady is primarily a gooseberry disease, rarely attacking the currant to a damaging extent. It is commonly referred to in Europe as the "American mildew" because of the fact that it was imported from this country about 1900, and when placed under English conditions became a very serious disease, being especially virulent to English varieties. In America it has been known since the early part of the last century and is probably native on our wild fruit.

Loss from Powdery Mildew.—The disease sometimes causes serious loss, altho it is never so destructive here as in the Old World. Occurring on the berries, it mars and renders them unsalable; on the leaves and stems it stunts the growth and impairs the vitality of the bush.

Susceptibility of Different Varieties.—English gooseberries grown in America are especially subject to mildew and frequently fail to produce fruit on account of the stunting effect. The Houghton among American varieties is regarded as especially susceptible.

Symptoms.—The disease usually appears first in shaded parts of the bush, where small, white, webby patches appear on the fruit, stem, or leaves.

On the stem they usually develop only on the young growth. The spots on the fruit enlarge, become darker in color and felt-like in appearance. They may almost entirely cover the berry and disfigure it to such an extent as to render it unsalable. On the shoots the spots enlarge and cover the entire surface with a fine felt-like mat which is powdery in appearance.

Cause.—The disease is caused by a surface mildew, *Sphaerotheca Mors-uvae.*

The fungus develops a webby growth of mycelium on the surface of the fruit, shoot, and leaf. It extracts nourishment from the epidermal cells thru small feeding organs which bore thru the external walls of these cells. Short club-shaped conidiophores are sent up over the surface of the mycelium and form chains of white conidia in such enormous quantities as to give the surface a white, powdery appearance. These conidia are carried to other parts of the plant or to other bushes.

Small, black, superficial perithecia are developed among the mycelial threads later in the season. In the perithecia the ascospores

are developed, and these are able to pass the winter uninjured by the cold. They serve to reinfect the plant the following season.

Control.—Spraying with lime sulfur (1-40) is effective for the control of mildew. The first application should be made when the buds open and other applications at ten-day intervals until at least five have been made. Since lime sulfur mars the fruit, it is better to use a solution of potassium sulfid (liver-of-sulfur) for the later applications. This spray is made by dissolving one ounce of potassium sulfid in two gallons of water. This mixture may be used in place of lime sulfur for all applications if desired. Dormant-strength lime sulfur used before the buds open seems to aid in controlling the malady.

CANE BLIGHT

The red currants are especially subject to a disease of the canes which results in the death of the entire bush. This disease is common in Illinois and on account of the wilting effect has often been ascribed to root troubles. In New York, cane blight is one of the most serious diseases of currants, especially in the Hudson valley region, where the disease was known as early as 1891. Its distribution thruout the fruit-growing region of the country has been easy because of the fact that the fungus lives over winter on the canes and is thus carried on the cuttings used for propagation.

Fig. 56.—Cane blight of currant showing black fruiting pustules

Symptoms.—About the last of June or the first of July, the young shoots show signs of wilting near the tips. During the summer and autumn the larger and older branches are gradually killed until much of the bush is destroyed. Black, wart-like bodies may be seen on the old canes which were killed the preceding season. These develop in parallel rows up and down the stem (Fig. 56).

Almost without exception there is present on the dead canes another fungus which produces brick-red pustules thru ruptures on the bark similar to those just described, but differing from them in being larger and not in parallel rows.

Cause.—The disease is caused by a fungus, *Botryosphaeria Ribis.*

This organism has a complex life history, during which three types of spores are pro-

duced. Infection of the young shoots probably takes place during the latter part of June. These wilt and die from the tip down. During July pycnidia are produced, containing what is known as the Macrophoma type of spores. The following season, on these same dead shoots, another type of pycnidium is produced containing Dothiorella spores. During the summer and autumn the perithecia are formed on these same shoots. The black masses, described above as breaking thru the outer bark on the old canes, consist of a mixture of pycnidia and perithecia (Fig. 56).

The ascospores formed in the perithecia are not necessary in the life history of the fungus, since the mycelium winters in the canes. The growth of the fungus mycelium in the tissues of the cane causes the death and sudden wilting of the young shoots. The mycelium grows down into the older stems and kills them as it progresses. Sometimes death of these older canes does not result until the following year. Frequently, several of the canes in the interior of the bush are killed while the outside ones survive.

Pleonectria berolinensis, the fungus which produces the brick-red fruiting bodies on the dead canes, is probably a saprophyte, but it is almost always present and serves as a good winter indication of the disease.

Control.—There is no known successful method of controlling cane blight. Care should be taken in selecting bushes for planting, and if the disease is discovered in a plantation, the bushes should be dug up and burned.

GRAPE DISEASES

Grapes are grown on a commercial scale in only a few sections of the state. However, the grape is an important fruit in Illinois since small vineyards are found in the neighborhood of all cities and since many city and country homes have a few vines to supply their needs.

In contrast to conditions in the grape-growing regions of eastern and western United States, the vineyards of Illinois have very few serious fungous diseases. Intensive grape growing in any area over a number of years, will, no doubt, increase the number of diseases. The three main diseases with which Illinois growers have to contend are black rot, anthracnose, and powdery mildew. Downy mildew rarely causes serious loss. It is fairly common on wild grapes thruout the grape-growing region and is not uncommonly found on the leaves of cultivated varieties, but never to a damaging extent. It will be treated here, however, since it may become much more common following a series of seasons favorable for its development.

BLACK ROT

Loss from Black Rot.—Grape growers do not ordinarily distinguish between black rot and anthracnose, both being spoken of as "the rot." Black rot has undoubtedly caused more loss and is more generally distributed than anthracnose. Since the spraying of grapes has become a general practice, the loss has not been very great.

As early as 1861, this disease was so prevalent in the grape-growing region about St. Louis as to cause serious epiphytotics. It is found wherever grapes are grown, but the loss varies greatly in different regions. Black rot was introduced into France about 1880 from the United States, probably thru the efforts of the French to secure phylloxera-resistant vines by importing them from America.

All parts of the plant are subject to black rot. It is usually noticed, however, as a leaf spot on the foliage and a rot on the fruit, the damage to the fruit being the more important.

Symptoms.—On the Fruit. The first evidence of black rot is a small white area on half-grown fruit. Later, a brown ring appears near the outer edge of the white area giving a "bird's-eye" effect similar to the condition in anthracnose. The berry shows a definite rotted area underneath the spot, and in the center of the lesion

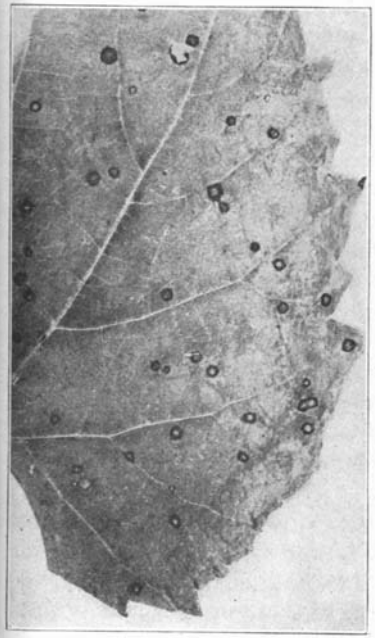

FIG. 57.—BLACK ROT OF GRAPE (Natural size)

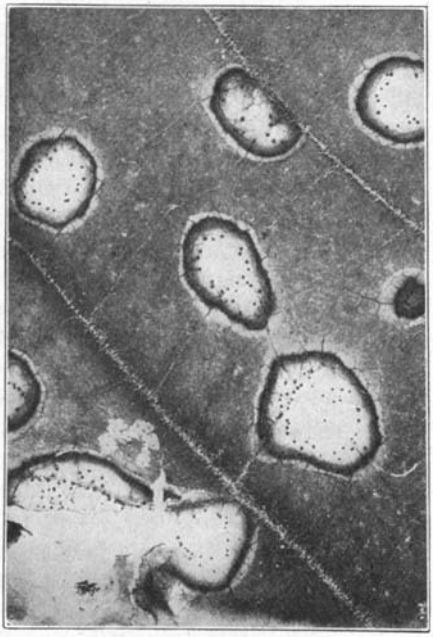

FIG. 58.—BLACK ROT OF GRAPE, SHOWING BLACK PYCNIDIA AT PERIPHERY OF SPOTS (Enlarged)

numerous black dots appear. The entire berry soon rots and becomes a shriveled, wrinkled, coal-black mummy.

On the leaves, the infection produces a definite light brown spot with a darker margin. In the summer a ring of black dots appears in the peripheral portion of the spot (Figs. 57, 58).

Cause.—The fungus producing this disease is *Guignardia Bidwellii.*

The organism has a life history similar to bitter rot and scab of apple in that there are two spore forms, pycnospores produced in pycnidia, and ascospores produced in perithicia. The pycnidia, the little black specks (Fig. 58), are formed on the fruit and leaf, and the pycnospores (conidia) are forced out in long, curled tendrils composed of thousands of spores. These may be carried by water or insects to other fruit or leaves, and there, if moisture is present, they germinate and cause infection.

After infection, it is usually from eight to eighteen days before the disease makes its appearance on the fruit and from ten to twenty-one days before it appears on the leaf. The fungus develops much faster during hot, dry weather, and consequently the spots appear correspondingly earlier.

Some of the pycnidia remain over winter and pycnospores are produced the following spring which may infect the new growth. In other cases the pycnidia are converted into perithecia in which asci are developed in the spring. The ascospores formed within the perithecia are discharged into the air with some force and may be carried by air currents to the young tissues, which they readily infect. The perithecia are produced in mummied fruit lying on the ground beneath the vines or clinging to the old vines. They may continue to discharge spores during the entire summer.

Control.—Usually a combination of sprays is used to control insects and various fungous diseases of the grape. (See page 142.) Spraying should be thoro and, when possible, the spray should be applied just before a rainy period. Careful study of the weather forecasts will make this possible.

Proper cultivation and the removal of all mummied fruit no doubt aid in reducing chances of infection by destroying sources of spore production.

POWDERY MILDEW

The "oidium," or powdery mildew, of the vine is interesting because it was owing to its ravages that the fungicidal value of sulfur was brought to the attention of fruit growers.

Loss from Powdery Mildew.—While the disease does not cause serious direct loss in Illinois, it is probably next to black rot in importance on account of its general prevalence. Loss of leaf function

and shelling of the fruit result from the attack of this mildew. The disease is especially serious in Europe, where it was introduced about the middle of the last century from Japan. For several years after it became generally distributed the loss was so great in France that thousands of vineyards were abandoned and the grape-growing industry was so seriously threatened that the nation was alarmed. The use of sulfur as a preventive of the disease was discovered about 1854, and altho there is still a great annual loss in France, it does not seriously interfere with grape production.

The mildew was introduced into America prior to 1859. It has always proved more serious in the western states than in the eastern, and more serious in the East than in the Mississippi valley region. A loss of 50 percent in western New York is sometimes sustained under epiphytotic conditions.

Symptoms.—Whitish patches about one-fourth inch in diameter appear during the course of the spring on the upper or lower surfaces of the leaves. These areas enlarge and coalesce until the greater part of the surface is covered by the grayish, powdery mildew. The leaf is stunted and usually curls inward, exposing the lower surface. The young canes, flowers, leaf stems, fruit, and fruit stems are also attacked.

When the blossoms are attacked, they fail to set the fruit. If the fruit is attacked, it fails to develop and falls off. Sometimes when the fruit is half grown before being attacked it remains on the vine, but it is deformed by unequal growth of the affected and unaffected parts and often cracks.

Cause.—This disease is caused by a fungus, *Uncinula necator.*

Like other powdery mildews it has a superficial mycelium which derives its nourishment by sending feeding organs into the epidermal cells of the host. The web-like growth of this mycelium may be seen in the white or grayish patches which appear on the under surface of the leaf. The mycelium sends up club-like conidiophores bearing chains of conidia, which are blown about over the vineyard. When these germinate they start a new patch of mycelium, which in turn extends itself over the leaves and berries and produces more conidia.

As the season advances, numerous minute, black perithecia are produced among the mycelial threads scattered over the infected area. These contain the asci and ascospores which serve to carry the fungus over winter. In the spring the perithecia disintegrate and the ascospores are liberated and carried to the leaves or shoots, where they germinate and start a mycelial growth, which in turn produces the summer spores for further infection.

Control.—Powdery mildew is controlled by application of the sprays used in the control of black rot and other grape diseases (see page 142).

In California, where black rot does not occur, sulfur dust has been employed altogether in the control of powdery mildew. This can be applied after the appearance of the disease, since it will kill the superficial mycelium and also prevent the germination of the conidia. It is cheaper and more quickly applied than Bordeaux. In New York it has been found that the application of sulfur dust occasionally causes serious injury to the vines.

DOWNY MILDEW

Loss from Downy Mildew.—In many grape-growing regions downy mildew is considered the worst enemy of this fruit. In Europe it has caused an enormous amount of damage, since European varieties of grape are much more susceptible to the disease and since climatic conditions there are more favorable for its development.

Downy mildew was introduced in Europe from America in 1878, probably on some imported American root-stocks which were used on account of their resistance to the insect phylloxera. In America the disease has been known since 1834 and has been most destructive in the northern states, especially about the Great Lakes. Illinois vineyards have never suffered severely from downy mildew, altho it is frequently found on both cultivated and wild grapes in this state.

Downy mildew affects leaves, berries, and tender vines. It causes loss thru the rotting and shelling of the berries, thru the total or partial destruction of the foliage, and thru the stunting of the shoots. The disease develops rapidly during wet, hot seasons and is seldom troublesome in dry seasons.

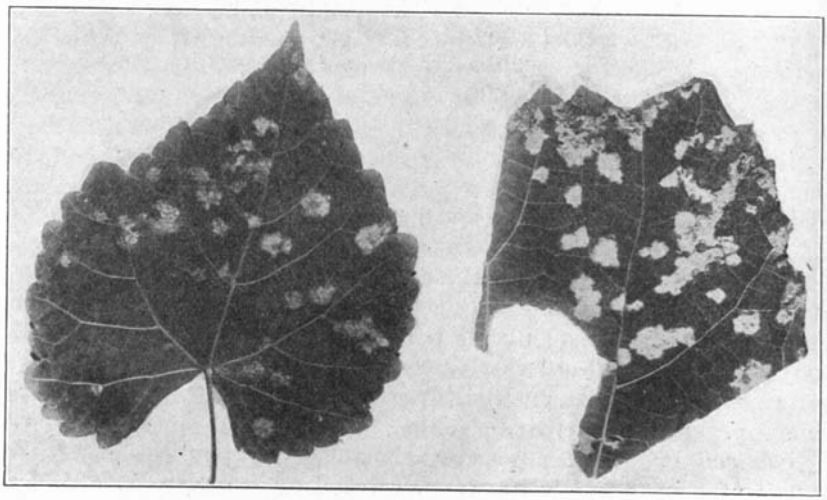

FIG. 59.—DOWNY MILDEW ON GRAPE LEAF

Fig. 60.—Downy mildew on stem of grape

Symptoms.—On the leaves the first evidence of the disease is the appearance of light-colored, irregular areas, about one-fourth inch in diameter, on the upper surfaces. If the under surfaces of these spots are examined, a grayish white, downy growth will be observed (Fig. 59.) Frequently the infection is so heavy that many such spots appear on a single leaf, coalescing more or less, and giving a mottled appearance to the whole leaf.

On the shoots, the disease frequently results in thickening and shortening the greater part of the current year's growth. The surface is covered with a heavy, downy, gray growth (Fig. 60).

On the berries, the first indication of the disease is a change of the normal green color to a bluish green or lead color. At the same time these berries are much harder than normal. In a short time the surface of the berry is covered with a mildew growth similar to that on the shoots and leaves. Later the berries may shell or, if retained on the vines, become wrinkled and mummified. The disease also attacks the flowers early in the season and sometimes appears on the fruit stalks.

Cause.—The fungus responsible for downy mildew of grapes is called *Plasmopara viticola.*

The organism develops resting spores (*oospores*) in the leaf tissues. In the spring these oospores germinate, producing branched conidiophores upon which a number of conidia are borne. These are scattered by the wind or by moisture to the leaves of the grape. The contents of each conidium, under moist conditions, divides into a number of small spores which break out and are capable of moving about in water by means of little swimming organs. These spores are called *swarmspores,* and they are produced thruout the spring and early

summer. The swarmspores are liberated, swim about on the wet surface of the leaf, and finally come to rest, sending germ tubes into the interior of the leaves thru the breathing pores, or stomates.

The mycelium formed from this infection grows in the tissues of the leaf, stem, and fruit, and later develops the spots characteristic of the disease. The downy masses seen on the surface are the conidiophores which are sent to the exterior from the internal mycelium. On these are borne conidia which behave in all respects like the conidia developed from the oospores. These conidia are carried to other vines and produce new infections thru the liberation of swarmspores.

The sudden and rapid development of the disease during warm, moist weather is due to the rapidity with which the fungus passes thru its life cycle. The oospores are formed in the leaves in autumn and carry the fungus thru the winter.

Control.—In Illinois it is not considered necessary to spray against this fungus alone, since the spray for black rot, which should always be applied, is usually sufficient to keep the downy mildew under control (see spray schedule, page 142).

ANTHRACNOSE

Black rot and anthracnose have been confused in the writings of vineyardists in this state, and as a result there is some uncertainty as to the extent of the latter disease and the damage it has caused in the past.

Origin and Distribution.—Anthracnose was first observed in the central part of the state about 1881, and was probably introduced from Europe, where it was previously known. The disease is generally prevalent thruout the grape-growing regions east of the Rocky mountains.

Loss from Anthracnose.—It is very fortunate that the Concord is practically immune to anthracnose. Most other varieties of commercial importance are susceptible. The disease may be very destructive, causing the loss of practically all the fruit and seriously damaging the vine. In 1909 it caused the loss of large quantities of fruit in Michigan, some vineyards losing from 60 to 70 percent of the crop on susceptible varieties. It is probably third in importance among grape diseases in this state.

Symptoms.—The lesions are found on all green parts of the plant. They are more pronounced on the green shoots, berries, petioles, and stems of the grape bunches.

On the shoots, small reddish brown, circular, slightly sunken spots appear. These enlarge, become oval in shape, and the central area becomes more sunken and gray. The spots at this time resemble the anthracnose of raspberries. Similar spots are found also on the tendrils, leaf petioles and larger veins, and on the fruit stems.

On the berries, the spots are at first dark brown and circular in outline. The central brown area later becomes surrounded by a bright red zone which gives a striking bird's-eye appearance when the fruit is green. The berries at first show no signs of rotting but are quite firm beneath the affected area. Later, however, they shrivel and become mummied.

The disease is rarely found on the foliage in this state but, according to some investigators, may cause a spotting.

Cause.—The anthracnose of grape is caused by a fungus, *Manginia ampelinum.*

The imperfect, or summer-spore, stage is known under the names *Sphaceloma ampelinum* and *Gloeosporium ampelophagum.* The imperfect stage only has been found in America, and it is probable that the ascospore stage plays little or no part in the life history of the organism.

The fungus probably lives over winter in the mycelial state in the shoots. Acervuli are produced in the lesions on the stems, and gelatinous masses of spores are pushed out from these. The gelatinous substance dissolves in water, and the spores are carried to new growth and to the developing berries, where new spots are produced. This continues thruout the season, infection taking place at any time when weather conditions are suitable. Rain and heavy dews probably play the most important part in the dissemination of the spores and spread of the disease.

Control.—Recently it has been found that the dormant sprays are important in controlling the malady. The application of winter-strength lime sulfur (1-8) during the dormant period, followed by the usual application of summer sprays (see page 142), will successfully control the disease. Cutting out badly afflicted shoots is also recommended.

WHITE ROT

White rot of grapes has not been reported as serious in this state, but it is probable that it has been confused with anthracnose and black rot by vineyardists. This malady is probably of American origin but it was first observed in Italy in 1878. In 1887 it was found causing serious trouble to the grapes in Missouri and has since been reported from a number of states in the East and South.

The disease is regarded as of little importance but there is evidence that it may cause great loss during some seasons. In southern Illinois a two-acre vineyard was observed where 50 percent of the bunches had some diseased berries and frequently entire bunches had been destroyed.

Symptoms.—The disease often appears first on the *fruit stalks,* causing their death and thus cutting off nourishment from the berries so that they wither.

On the berries, a brown rot is produced which soon involves the entire berry. Usually berries are affected when they are softening preliminary to ripening but they may become affected when ripe. Frequently only a few berries in each bunch are diseased. The fruit remains plump and juicy until it is entirely rotted, then shrivels and finally forms a dark-colored mummy. Numerous black or dark brown pustules appear on the surface of the lesions.

Cause.—White rot is caused by a fungus, *Coniothyrium diplodiella.* Pycnidia are produced beneath the epidermis of the rotted areas on the fruit. These fruiting bodies are very numerous and produce enormous numbers of spores, which exude as white masses during damp weather. These pycnospores probably live over winter in the mummied fruit and in the dead fruit stalks. They infect the developing fruit the following season or, alighting on the fruit stems, produce cankers.

Control.—Little experimental work has been done for the control of white rot. It is believed, however, that the sprays for black rot given in the spray schedule probably will control this malady.

RIPE ROT

A ripe rot of grapes is sometimes observed in Illinois, but rarely does it cause serious loss. The berries are not attacked until they are nearly mature, when definite, circular, reddish brown, sunken, lesions are produced. The entire berry is finally involved and, unlike berries affected with black rot, it drops at the slightest jar of the vine.

Cause.—The fungus causing the disease, *Glomerella cingulata,* is the same as that producing bitter rot of apples. For a discussion of the life history of the organism see page 26.

Control.—Control measures against this disease are difficult on account of the mature condition of the fruit at the time of infection. Sprays applied late in the season mar the fruit and render it unsalable. The disease is rarely of sufficient importance, however, to warrant special spray practice.

SPRAY SCHEDULE FOR GRAPES IN ILLINOIS

Dormant spray, lime sulfur (1-8)
Bordeaux mixture (4-4-50)

a. When shoots are from 8 to 12 inches in length
b. Just before the flower buds open
c. Just after the blossoms fall
d. 10 to 14 days later
e. 10 to 14 days later

Add arsenate of lead when spraying against insects.

STRAWBERRY DISEASES

In Illinois strawberries rank next to apples in importance from a commercial standpoint. Most small cities thruout the state have local gardeners who supply their needs from patches of from one to five acres. In addition there are several large sections devoted to growing strawberries for the Chicago wholesale markets.

Fortunately there are few diseases of destructive nature to which strawberries are subject. The leaf spot and mildew are the only vine diseases, while the rots of the berry are largely confined to overripe or poorly cared-for fruit. The rotting of berries in the patch and in transit has not received the attention it merits.

LEAF SPOT

Loss from Leaf Spot.—The only disease of strawberry vines of any consequence in Illinois is leaf spot. This is constantly present on the leaves of most varieties of strawberries tho it seldom becomes so serious as to cause the death of the vines or greatly impair their vitality and growers rarely consider it as a menace to their crop. It is hard to estimate the losses due to the disease and difficult to determine whether or not it pays to spray in order to control it.

The disease is peculiar in that during cloudy, wet seasons it is rarely as bad as when the seasons are relatively dry. A moderately wet season with plenty of sunshine seems to be most favorable for leaf spot. Undoubtedly, if a season favorable to the development of the disease is followed by a dry summer, the vitality of the developing plants is seriously reduced and a full crop cannot be expected the following season. Frequently the spotted leaves are more seriously sun scalded than the uninjured ones and consequently there is a greater exposure of the fruit to the sun. During the first year of bearing, leaf spot rarely causes much trouble, but as the patch becomes older the trouble increases.

The disease is much more serious in southern Illinois than in the central or northern portions.

Susceptibility of Different Varieties.—Varietal resistance is marked where a number of varieties are grown together, but the relative resistance of any particular variety is not constant in different localities. Buback, Haverland, Aroma and Dunlap are among the least troubled, while Warfield, Gandy, Brandywine, Miner, William Belt, and Michels Early are among the most susceptible. There is not sufficient difference in varieties, however, to warrant discarding an otherwise good variety.

Symptoms.—On the leaves the disease appears at first as minute, purplish red spots especially evident on the supper surfaces. Later the spots enlarge and become evident on both surfaces. They remain

circular in outline but without a sharp line of demarcation. A small white or light brown area of dead tissue next appears in the center. The purplish ring about this central white area renders the spot unmistakable (Plate I, b). The spots may be evenly distributed or may occur more or less grouped on one portion of the leaf. When occurring closely associated they often fuse, forming an irregular, discolored area which frequently turns brown and dies before the spots are fully developed.

The disease also develops *on the leaf petioles* and *on the fruit stems*. The appearance on these organs is much the same as on the leaf. In some cases the fruit stems or pedicels are so weakened by the malady as to reduce the size and quality of the fruit.

Cause.—The fungus causing leaf spot of strawberry is called *Mycosphaerella Fragariae.*

The spots are produced by a localization of the fungus mycelium in these areas. Conidia are formed freely on both surfaces of the lesions. They are scattered thruout the patch during the entire summer and cause new infections on the young leaves as they appear, provided the conditions for infection are suitable.

The fungus remains in the leaves over winter, and in the spring another crop of conidia is produced. In addition sclerotial bodies are formed on the surface of the leaf in the fall. These rest over winter and in the spring produce conidiophores and conidia. A perfect stage which aids in carrying the fungus over winter is also formed. Perithecia are formed in the spots in the fall and mature in the spring, giving rise to ascospores.

The fungus is found also on several weeds which are closely related to the strawberry, and these aid in spreading the disease.

Control.—Bordeaux mixture applied before the blossoms open, and at intervals after harvesting the fruit, will check the disease sufficiently to prevent serious loss of leaf surface. It is a question whether, under ordinary conditions, it is worth while to spray for the control of leaf spot. This depends upon the severity of the disease.

In setting out plants, pinching off most of the old leaves not only reduces the possibility of infection but also is good horticultural practice.

POWDERY MILDEW

Loss from Powdery Mildew.—No great loss has been reported in Illinois strawberry patches from powdery mildew. It is a disease, however, with which all growers should be familiar, since serious epiphytotics have been known to occur in other sections of the country, causing great losses and alarming growers who were ignorant of the nature of the malady.

The disease was first noticed in New York state about 1886 and was observed in Massachusetts in 1891. It seems to be much more common in the eastern section of the country than in the central states.

Little is known concerning the relative susceptibility of Illinois varieties of strawberries.

Symptoms.—The first evidence of the disease apparent to the grower is a curling of the leaves so that the under sides are exposed. When these leaves are examined it will be seen that there is a fine webby growth on the under surfaces, with a white, powdery coating where the leaves are somewhat protected. The leaves attacked frequently dry up and die, especially if there is little rain.

Cause.—Powdery mildew is caused by a fungus, *Sphaerotheca humuli.*

The fungus mycelium is entirely superficial. It does, however, send minute feeding organs into the epidermal cells of the leaves and leaf stems which weaken the plant by extracting needed water and food materials. Thruout the summer white, powdery spores are continually produced from conidiophores arising from the web-like mycelium. These conidia are light and easily blown about by air currents, thus infecting other plants. Later in the season minute black specks, the perithecia, appear over the under surfaces of the leaf blades and on the petioles. In each perithecium a single ascus is developed. The ascospores carry the fungus over winter, are released in the spring thru the disintegration of the perithecium, and cause new infection.

Control.—No methods of control have been tried against this fungus, but there is good reason to believe that sulfur dust will check the mildew, as it is commonly used successfully against surface mildews on other plants, such as the grape and hop. A good grade of finely powdered sulfur should be used and it is best applied with a small bellows especially designed for dusting grapes and other small fruits.

Lime sulfur or Bordeaux will probably control mildew.

BLACK MOLD

Loss from Black Mold.—This rot is the most destructive of those which affect strawberries in market. It is also common in the field but not so prevalent as gray mold. Black mold is a common cause of "leak" in market fruit. It usually affects only overripe or carelessly handled fruit, but during wet seasons may appear in spite of every care. This rot is not confined to strawberries but occurs on many other fruits and vegetables.

Symptoms.—The affected fruit, either in the patch or after picking, becomes mushy and watery at points where it has been bruised. The tissues collapse and the juice exudes. When the fruit is held under moist conditions the surface becomes covered with a white, powdery mold which later turns black.

Cause.—The disease is caused by a mold fungus, *Rhizopus nigricans.*

The fungus grows on decaying vegetable matter such as old bread, overripe fruits, and vegetables. The spores are developed in enormous numbers and are omnipresent. When they alight on the bruised surfaces of strawberries they germinate and quickly start growth and decay in the tissues. The rapidity of the rot depends upon the temperature at which the fruit is held. It has been found that the fungus rarely enters uninjured fruit, but it is almost impossible to handle ripe strawberries in such a manner as to prevent bruising.

The fungus mycelium, after spreading thruout the tissue of the fruit, appears on the surface, where it sends up clusters of fruiting stalks. The ends of these stalks swell into globose knobs (sporangia) in which quantities of black spores are produced. Before these spores mature they are light in color, giving the white or gray moldy appearance previously described. The black spores are released by the rupture of the sporangium wall and being very light are carried long distances by air currents. They are resistant to drying and may live for months.

Control.—The fact that the spores of this fungus are so generally present and so resistant to adverse environmental conditions, makes the control of rotting unusually difficult. The fruit should be carefully handled at all stages to avoid bruising. It should be kept at as low a temperature as possible in order to prevent rapid development of the fungus. Pickers should carefully discard all injured or slightly rotted fruit. It has been found that washing strawberries before shipping does not necessarily increase the amount of rot. If washing is practiced, the boxes should be dipped in clean cold water just before shipping, thus quickly reducing the temperature. The wet fruit and boxes should be placed in iced cars as soon as possible.

GRAY MOLD

Loss from Gray Mold.—This rot is more destructive in the field than black mold and rivals the latter in the amount of damage done in transit and in markets. The name brown rot is frequently used by growers. The disease is especially destructive during cloudy, wet seasons and rarely causes serious loss during seasons when there is plenty of sunshine. Gray mold is generally distributed but is

probably most common in the southern Mississippi valley. There is no marked difference in varietal susceptibility.

Symptoms.—Gray mold usually appears on the fruit, but fruit pedicels and other parts may be attacked. The berries are commonly attacked where they come in contact with the wet mulch. Here the first indication of the rot is a yellowish brown area which slowly spreads over the entire berry. The flesh remains fairly firm in texture and no "leaking" is evident. The fruit and fruit stem later become entirely covered with a dense, gray mold. Frequently the disease involves an entire fruit cluster and the gray mold appears over the stems, young fruit, and even the blossoms.

The fruit rots in the market in much the same manner as in the field, altho the gray surface mold is not so commonly observed. Small brown spots first appear, and later these spread with more or less rapidity, depending upon the temperature.

Cause.—The fungus causing this rot is usually called *Botrytis cinerea.*[1]

The gray mold appearing over the surface of the fruit consists of thousands of spore stalks (conidiophores) on the ends of which the spores are borne in grape-like clusters. These spores are carried by air currents over the entire patch or over the fruit in market. If weather conditions are favorable, the spores germinate and gain entrance to the fruit or fruit stem. The mycelium grows thruout the tissues of the host producing the characteristic symptoms. The spores of this fungus are almost omnipresent since it lives on many kinds of decaying vegetable matter.

Control.—The most effective control of Botrytis rot is secured by careful cultural methods. The plants should be set some distance apart so as to prevent closely matted rows. Weeds should not be allowed to grow between the rows since these hold the moisture and shade the fruit. Well-drained soil should be selected for planting when possible. Where the rainfall is normally heavy, straw mulches are to be preferred to manure or leaf mulches.

In transit and in market the fruit should be held at a low temperature since the spread of the rotted area is very slow when the berries are cool. Most of the rot in transit is due to previous infection in the patch and can be eliminated by careful sorting at the time of picking.

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[1]There is some question concerning the correct specific name of the Botrytis causing this rot.

GLOSSARY[1]

Acervulus (acervuli) An open fruiting body of the summer or asexual stage, corresponding to a pycnidium but not covered.

Aeciospore A spore of the rust fungi borne in an aecium.

Aecium (aecia) A fruiting body of one stage of the rust fungi, usually cup-shaped.

Apothecium (apothecia) A cup-shaped, ascus-bearing, sexual fruiting body of the Ascomycetes. See Perithecium.

Ascomycetes A group of fungi.

Ascospore A spore of an ascomycete.

Ascus (asci) A sac-like structure in which ascospores are borne, usually eight in each ascus.

Bacterium (bacteria) A simple, one-celled plant which reproduces by fission.

Canker A diseased area in the bark.

Cilium (cilia) A thread-like organ by which the swarmspores of fungi and some bacteria move.

Conidiophore A stalk which bears conidia.

Conidium (conidia) An asexual fungus spore.

Cuticle A waxy layer which covers exposed plant surfaces, such as leaves, young twigs, and fruits.

Epiphytotic The appearance in severe form of a plant disease in a given locality; corresponding to an epidemic among humans.

Fruiting body or **Fruit body** A complex spore-bearing structure, usually of a definite form (apothecium, pycnidium, perithecium, aecium, etc.).

Fungus (fungi) A plant of comparatively simple structure, lacking leaf-green (chlorophyll). It has no root, stem, or leaf. It reproduces mainly by means of spores of a sexual or asexual character (conidia, ascospores, aeciospores, swarmspores, etc.).

Germ tube The "sprout" of a fungus spore. The beginning of the mycelium.

Haustorium (haustoria) A feeding organ sent into the plant cells to absorb nourishment.

Host A plant upon which a parasite lives.

Hypertrophy An abnormal enlargement of plant parts.

Hypha (hyphae) The individual thread of the vegetative part of a fungus. The hyphae make up a mycelium.

Infection The act of producing a disease.

Lesion A diseased area.

Mycelium The system of threads (hyphae) making up the vegetative portion of a fungus.

Oospore A sexual spore of the downy mildews.

Parasite An organism which lives on, and at the expense of, another living organism for at least a part of its life.

Pathogene An organism which produces disease.

Pathogenic Capable of producing disease.

Pathological Condition of being diseased.

Perithecium (perithecia) A closed, usually flask-shaped, ascus-bearing fruit-body. See Apothecium.

Pycnidium (pycnidia) A closed, asexual fruiting body, usually globose or flask-shaped. See Acervulus.

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[1]The definitions here given are restricted to their application in this circular.

Pycnospore A conidium; an asexual spore borne in a pycnidium.

Rhizomorph A thick, root-like strand composed of compact hyphae.

Saprophyte An organism living on dead organic material.

Sclerotium (sclerotia) A firm, tuber-like structure composed of compact hyphal elements.

Seta (setae) A minute bristle.

Sporangium (sporangia) A sac containing asexually produced spores.

Spore A minute reproductive body corresponding in function to a seed in the higher plants.

Sporidium (sporidia) One of the spore forms of the rusts.

Stomate A breathing pore found in the green parts of plants.

Stroma (stromata) A thickened mycelial structure in or on which fruiting bodies are produced.

Swarmspore A spore capable of moving by means of a cilium or cilia.

Teliospore A spore form of the rusts.

Urediniospore The summer-spore form of rust fungi.

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