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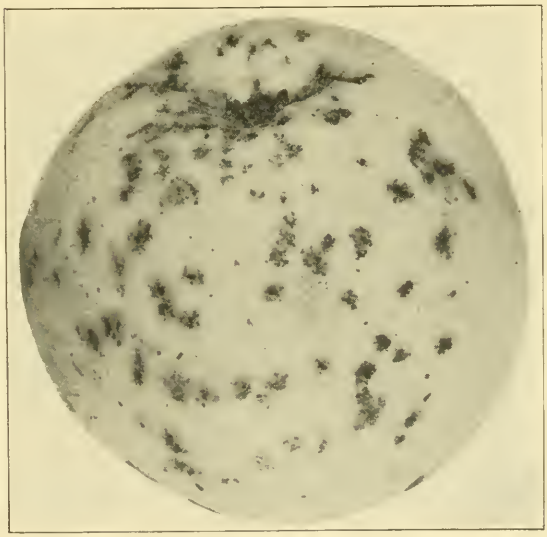
AGRICULTURAL EXPERIMENT STATION

DEPARTMENT OF BOTANY

SOME APPLE DISEASES AND THEIR TREATMENT



FRUIT SPOT

By CHARLES BROOKS

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

NEW HAMPSHIRE COLLEGE OF AGRICULTURE AND THE MECHANIC ARTS.

NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION

DURHAM, N. H.

The bulletins of the Experiment Station are published at irregular intervals and are sent *free* to all residents of New Hampshire requesting them.

SOME APPLE DISEASES AND THEIR TREATMENT.*

CHARLES BROOKS.

The growing interest in the production of high grade fruit has brought to the New Hampshire Agricultural Experiment Station a constantly increasing number of inquiries in regard to apple diseases and their treatment. It is the purpose of this bulletin to answer such inquiries more fully than can be done by letter and also to make available to the people of the state some of the results that have already been published in more technical form in the biennial reports of the experiment station.

THE NATURE OF PLANT DISEASES.

The term *disease* may be applied to any unhealthy or abnormal condition in a plant. Such a condition may be due to faulty nutrition, unfavorable climatic conditions or to the presence of foreign organisms such as fungi and bacteria. It is with the latter class of troubles that this bulletin deals in particular.

The *bacteria* and *fungi* are themselves plants, but belong to the lower forms of life and are very different from the familiar green plants in their manner of reproduction and in their method of obtaining food. Because of their lack of *chlorophyll* or green coloring matter they are unable to make their own starch and sugar food materials, and are therefore compelled to depend upon other plants for the preparation of a large part of their nutriment. They feed upon both living and dead organisms. Those living upon dead organic matter are known as *saprophytes*. The moulds that destroy stored vegetables and fruits and the toadstools and mushrooms of the pastures and forests are familiar examples of *saprophytes*. Fungi that obtain their food from living organisms are known as *parasites*. The plant upon which a parasite lives is called its *host*.

*This Bulletin is a revision of Bulletin 144, the edition of which is exhausted.

The vegetative portion of a fungus consists of minute threads known as *hyphæ*. A mass of these hyphæ is spoken of collectively as the *mycelium*. The white thread-like growth in mushroom spawn is the mycelium. It is this same mycelium which later spreads thru the mushroom bed to obtain the food with which to form the mushroom. With parasitic fungi the mycelium spreads between or into the cells of the host and absorbs its food material from them. The parasite usually obtains its own food to the great detriment of the host.

Fungi form *no seeds* but are reproduced by means of *spores*. These serve the same purpose as seeds but are produced in much greater numbers and are much more simple in structure. They are too small to be seen with the eye and so light that they are readily scattered by the wind.

Spores may be divided into two classes, the *summer spores* and the *winter spores*. The former are produced in enormous numbers and serve for the spread of the disease in the summer. They are usually cut off from the ends of special hyphæ known as spore stalks or *sporophores*. The winter spores can endure more unfavorable conditions and serve to carry the disease over the winter and thru dry seasons. They are usually produced in a special protective body known as a *pycnidium* or *perithecium*. The spores that are produced in perithecia are enclosed in sacs called *asci*.

Spores germinate by sending out a germ tube. This tube or hypha may enter the host tissue and develop a new mycelium there. The breathing pores of the leaves and fruit and wounds on the limbs and the trunk of the tree furnish opportunities to gain entrance to the host plant. The fact that the spore can germinate only in the presence of moisture and that the germ tube is thin-walled and delicate gives an opportunity to destroy it before it gains entrance to the host by spraying the host plant with some substance which will be poisonous to the germinating spore and which will slowly dissolve in the dew or other moisture that may be on the plant. The secret of successful spraying is in applying poisons of such a strength and in such a manner that the spores will be killed without injury to the host. When a fungus once gains entrance to the host there is little opportunity to attack it, hence sprayings made after a disease is

thoroly started are usually inefficient and often without evident results.

Heavy dews and cloudy, damp weather are favorable to the development of fungous diseases. The weather plays so important a part in this connection that it is sometimes given the entire credit for the disease. It must be borne in mind, however, that the real cause of the disease is the fungus itself.

Much can be done towards the prevention of diseases by the proper selection of an orchard site and by careful and thoro pruning. Orchards located on high land with good air drainage are much less susceptible to fungous diseases, and also to winter injury, than those in the valleys. If a tree is pruned so that sunlight and air have free access to all its parts the opportunity for infection by fungi is greatly reduced.

APPLE SCAB.

Venturia Pomi (Fr) Wint.

The scab is one of the most serious diseases of the apple in New Hampshire. Some varieties, such as the McIntosh, can scarcely be made to produce salable fruit without thoro treatment for its prevention. The disease appears first on the leaves. Here it may be evident early in June as slightly elevated spots of a lighter green color. At this stage the mycelium of the fungus is largely beneath the cuticle. It soon breaks thru to the surface, giving the leaf a velvety, olivaceous appearance (Fig. 1). Spores are produced in abundance and serve as the chief source of infection for the fruit. As a result of the fungous attack the leaves often become distorted and finally fall early in the season. The leaf surface is thus greatly reduced before

Fig. 1.—Apple Scab as seen on the foliage.

the end of the summer and the food supply of the tree similarly decreased.

It is on the fruit that the fungus produces its most characteristic and serious effects. Here it forms superficial olive colored spots known among apple dealers as "scab," "fungus" or "black spot" (Fig. 2). The spots are usually 1-8 to 1-2 of an inch in diameter. The mycelium begins its development beneath the cuticle, but soon sends up erect sporophores (spore stalks), which break thru to the surface to free their spores. (See A in Fig. 6.) The spores and sporophores give the spot its sooty,

Fig. 2.—Apples affected with Scab. (Lamson.)

olivaceous appearance. The marginal portion of the ruptured cuticle usually remains, giving the spot a light gray border. The fungus checks the growth in the adjacent tissue to such an extent that apples attacked early in the season often become dwarfed and one-sided, and sometimes badly cracked (Fig. 2).

The underlying portions of the apple are protected by the formation of a corky brown tissue beneath the scab. This protection is only partial, however, as scabbed apples wither rapidly in storage and the scab spots are quite commonly the point of origin for rots. Even slightly scabbed apples are, therefore, unfit for anything but immediate consumption.

The majority of the scab infections are made early in the season, but there is often a second spread of the disease in August. The young scab spots on the fruit at gathering time are evidence of this late attack. They do not, however, show the total amount of damage done by a late spread of the disease, as young scab colonies may continue to develop in storage and unsprayed apples apparently free from scab may develop the disease in storage if taken from an orchard in which a late spread of scab occurred. These scab spots that develop in storage must have their origin either from colonies that were too small to be noticed at the time of picking or from spores carried into the barrel with the fruit.

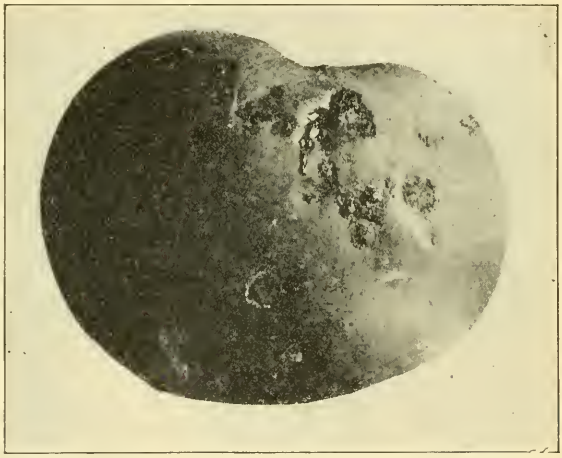


Fig. 3.—Scab on cold storage apple.

The scab fungus, like most other plants, is greatly checked in its growth by low temperatures. Its greatest development on stored fruit can therefore be expected in barrels from cellar storage or which are delayed in reaching the cold storage plant. In some seasons there has been heavy loss from the development of scab on cold storage apples. Storage experiments have shown sprayed apples to be largely or entirely free from this trouble.

One familiar with the disease as it occurs in the orchard is inclined at first sight to call the storage trouble a separate and distinct disease (Fig. 3). The fungus makes an unusual development beneath the cuticle before breaking thru and the mycelium is very dark in color. Consequently black, sunken spots develop on the apple and sometimes attain a diameter of one quarter of an inch before any break is evident in the skin (Fig.

4). The cuticle is finally ruptured and the usual form of spore and sporophore exposed (Fig. 5).

Late in the fall perithecia begin their development on the fallen leaves (Fig 6). They reach maturity by the following spring, and their spores are scattered in April and May. They are blown to the young foliage and start the disease anew. The production of this perithecial stage is especially common when the leaves fall upon the sod and are protected by their own number or by being partially covered with grass.

Treatment. The disease can be controlled by spraying. To be most effective the sprayings must be made before the fungus has gained entrance to the host as when it is once beneath the cuticle it may continue to develop in spite of the application of

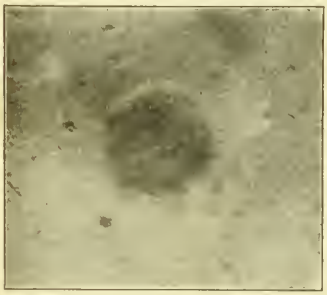


Fig. 4.—Early stage.

Fig. 5.—Later stage.

Scab Spot on Storage Apples.

fungicides. In badly affected orchards it is advisable to make a spraying before the leaves are out. At this time copper sulphate, 1 pound to 25 gallons, may be used, or a strong Bordeaux or lime-sulfur solution. A second spraying should be made after the leaves have expanded and before the flower buds open. Bordeaux or lime-sulfur may be used for this and for later applications. A third spraying should be given when most of the petals have fallen. This application is the most important of the season. When the disease is at all serious two more sprayings are needed, the fourth about three weeks after the third and the fifth early in August to prevent a late spread of the disease. For a discussion of fungicides see pages 29–32. The fact that the fungus winters in the leaves makes it evident that much may be accomplished by their destruction. A practical demon-

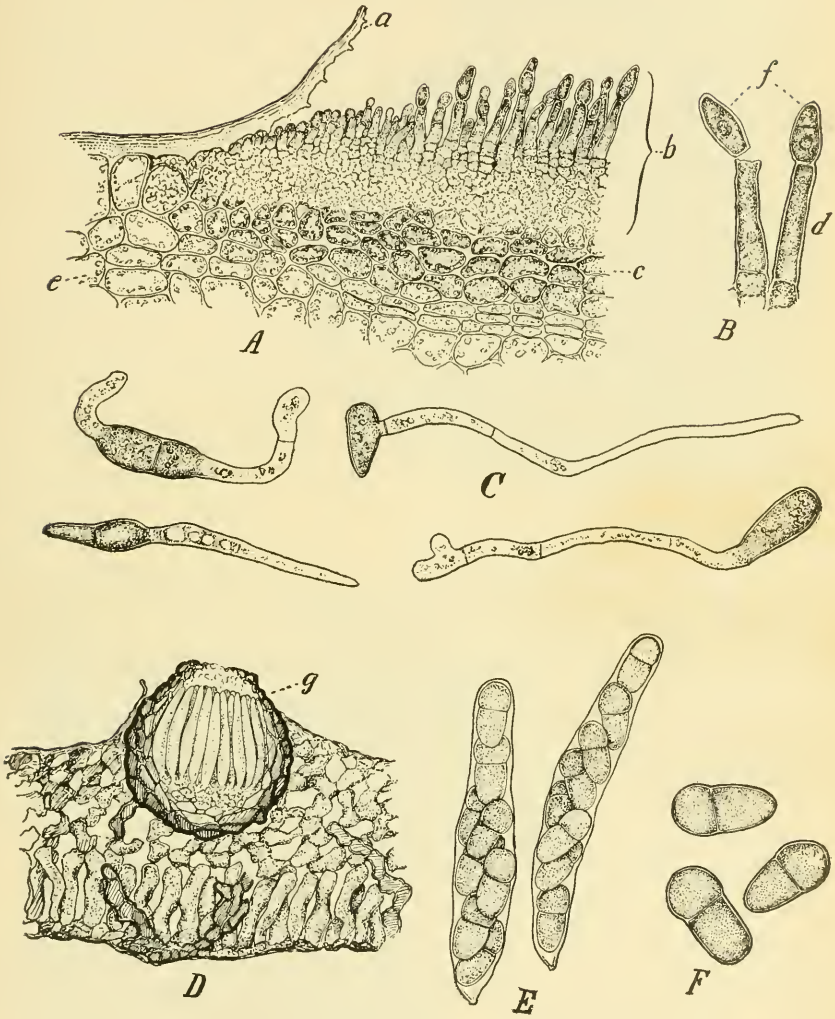


Fig. 6.—Microscopic Structure of the Scab Fungus. *A*.—Portion of a section thru a scab spot on an apple showing the fungus; *b*, spreading under and lifting the cuticle, *a*; *c*, partly disorganized cells of the apple; *e* healthy cells of the apple. *B*.—Two spore-bearing stalks (sporophores) giving rise to summer spores *f*. *C*.—Spores germinating. *D*.—Portion of a section thru an affected leaf of apple which has lain on the ground over winter and has given rise to the winter spore stage; *g*, spore case (perithecium) containing a bundle of spore sacs (asci). *E*.—Two spore sacs (asci), more highly magnified, each containing 8 two-celled winter spores, three of which are shown at *F*. (After Longyear.)

stration of the value of such treatment was obtained in the spring of 1909. The results were secured in two McIntosh orchards, which had been under observation for several years. Both had been seriously affected with scab each year, and the per cent. of loss had been approximately the same in the two. Both orchards were in sod. About the middle of April a fire escaped from a sugar camp and swept over the entire area of one of these orchards. Not a scab spot could be found in this orchard the following summer, while the disease was quite common in the other orchard. The danger of injuring the trees makes the above treatment questionable. In the case mentioned a strong wind drove the fire across the orchard so rapidly that little injury was done. Early plowing might be of value in leaf destruction.

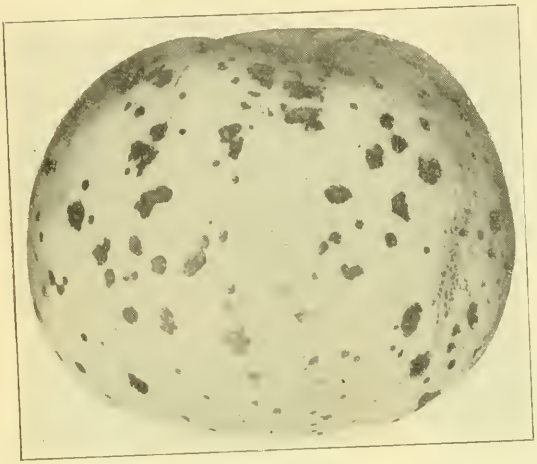


Fig. 7.—Fruit Spot.

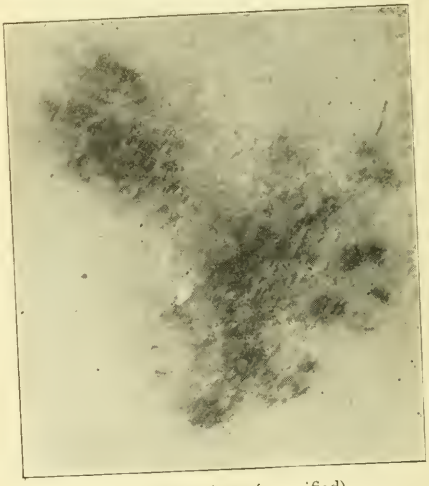


Fig. 8.—A single Spot (magnified).

FRUIT SPOT.

Phoma Pomi Passer.

This disease is of very common occurrence in New Hampshire and is found as far south as Maryland and Virginia and as far west as Michigan. It is not so destructive as the

scab, but often causes otherwise perfect fruit to go as seconds. It is found on almost every variety of apple, but Baldwins and Talman Sweets are especially susceptible. The disease appears about the middle of August. At this time it may be seen as spots of a deeper red on the colored surface of the apple and of a darker green on the lighter portion. As the season advances, the spots become more prominent. They become slightly sunken and more highly colored. (Frontispiece.) Numerous black specks appear, sometimes causing the center of the spot to have an almost uniformly black appearance (Fig. 8). The tissue beneath the spot is rendered brown and corky to a depth of several cells (Fig. 9). Cold storage

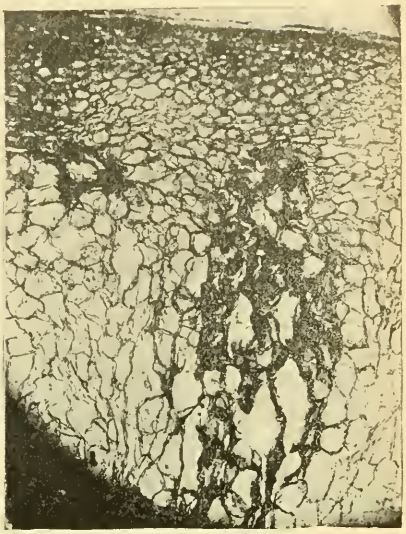


Fig. 9.—A section thru a Fruit Spot. The corky cells beneath the epidermis are shown above, while below are seen the brown and withered cells produced in the later development of the spot. The fungus can be seen in the pocket in the center.

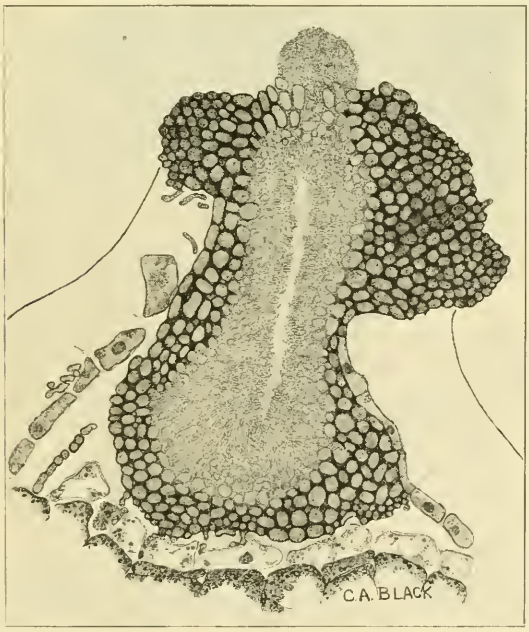


Fig. 10. A pycnidium of *Phoma Pomi*. The escaping spores may be seen above.

seems to check the development of the spots, but in cellar storage they often become more sunken and spread deeper into the tissue of the apple. They become brown and are much enlarged sometimes attaining a diameter of one half inch (Fig. 7).

In late stages of the disease numerous minute black elevations appear in the spots, caused by the development of pycnidia beneath the epidermis. The pycnidia are sometimes arranged in the form of a circle. They break through to the surface and set free numerous minute spores (Fig. 10).

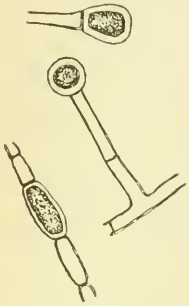


Fig. 11.—Chlamydospores from a fruit spot.

Thick walled spores known as chlamydospores are common in the apple tissue and are probably important in carrying the disease over the winter (Fig. 11). Another spore that is found in the host tissue and is extremely common in cultures of the fungus is shown in Fig. 12. These spores are produced in indefinite numbers from knob-like projections on the side of the fungous threads (Fig. 13).

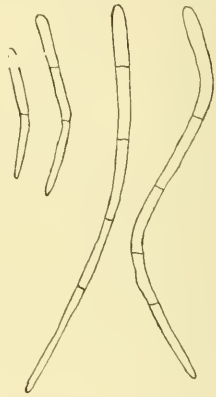


Fig. 12.—Spores of *Phoma Pomi* from a fruit spot.

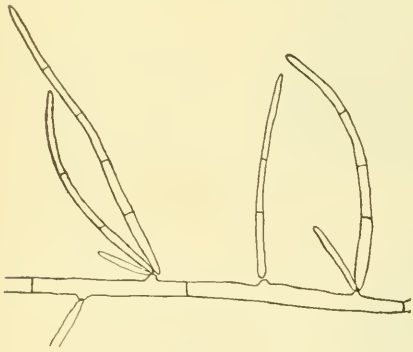


Fig. 13.—Spore formation of Phoma Pomi in cultures.

Recent experiments[1] have shown that the fungus causing the fruit spot of apples is also responsible for a similar spot on quinces known as "quince blotch." The disease may spread from one host to the other.

Treatment. The fungus does not attack the apples until they are nearly grown. Con-

[1] Brooks, Charles, and Black, Caroline A. Apple Fruit Spot and Quince Blotch. Phytopathology II, 63–73, 1912.

sequently, sprayings made in late June or early Julyare usually as effective if not more so than those made earlier in the year. However, orchards that have received sprayings three and four for scab will not usually require later spraying for fruit spot. See page 32. Both Bordeaux and lime-sulfur have given satisfactory results.

BITTER PIT.

The disease known as "Bitter Pit," "Fruit Pit," or "Baldwin Spot" is sometimes quite serious on New Hampshire apples.

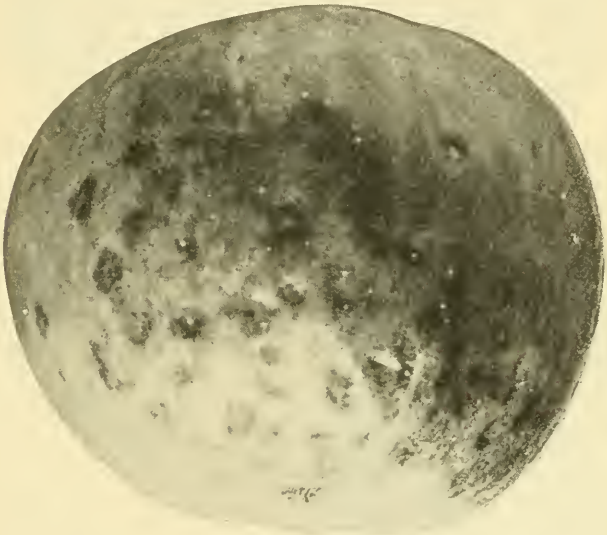


Fig. 14.—Bitter Pit.

It is found in various sections of the United States and Canada and is a very serious disease in Australia and South Africa. It is particularly common on Baldwins and Northern Spies.

It is somewhat like the fruit spot in appearance, yet it is distinctly different upon close observation. In the early stages of the disease the spots may show no difference in color from the surrounding portions of the apple and only the slightest depression. At this time they have the appearance of numerous minute bruises. They soon become conspicuous as sunken areas from 1-8 to 1-4 inch in diameter (Fig. 14). The depres-

sions are somewhat hemispherical in shape. As they continue to develop they become more highly colored than the surround-

Fig. 15.—Bitter Pit. Brown streaks in the flesh of the apple.

ing portions and later take on various shades of brown. At first this coloration shows thru from rather deeply seated tissue, but later the surface tissue also becomes a dark brown. As the disease advances, the spots situated near each other often become confluent, developing into one large spot or pit. The pronounced depressions in the later stages of this disease are characterized much better by the term *pit* than by that of *spot*.

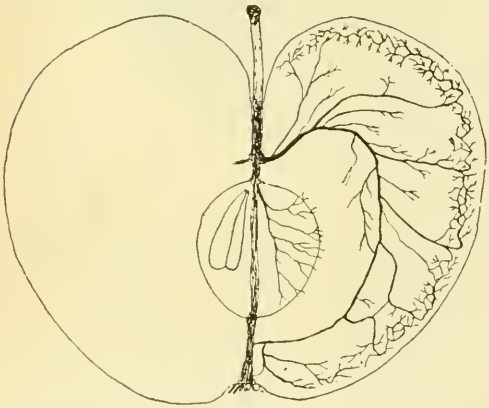


Fig. 16.—A sketch of a portion of the vascular system of an apple.

In late stages of the disease numerous spots of brown tissue are found in the flesh of the apple (Fig. 15). Closer study shows

that these are in reality numerous bands of diseased tissue that follow the irregular course of the food-conducting vessels. These vessels are abundantly distributed in the portion of the apple that is within 1-2 inch of the surface (Fig. 16). The brown streaks are correspondingly abundant in this portion of the apple (Fig. 15). The brown streaks may occur without the pitting on the surface. This condition is particularly common on apples in cellar storage.

The disease is reported to be worst in warm, rainy seasons. It is especially common on large apples and on the fruit from trees that are in an unhealthy condition. It may occur, however, on trees in almost every condition of age and vigor. It is not due to fungi or bacteria. Nothing definite can be given as to prevention.

SOOTY BLOTCH AND FLY SPECK.

Leptothyrium Pomi (Mont. & Fr.) Sacc.

The Sooty Blotch and the Fly Speck of the apple were formerly thought to be caused by two different fungi, but a recent writer[1] claims that one fungus is responsible for the two diseases. The names given these two effects characterize their appearance. The former produces blotches 1-8 to 1-2 inch in diameter on the fruit (Fig. 17) and the latter numerous minute specks. They give the apple a sooty appearance that depreciates its market value. The fungous growth is entirely on the surface of the fruit, and hence the disease is especially dependent upon moist weather for development.

Fig. 17.—Sooty Blotch of apple

Treatment. The disease is readily controlled by spraying. Thoro pruning is important, and if light and air have free access to the fruit the disease usually gives little trouble.

[1] B. F. Floyd in Duggar's Fungous Diseases of Plants, p. 367, 1909.

APPLE RUST.

Gymnosporangium spp.

Apple rust is a widely distributed disease, and in some sections is quite injurious. It is of common occurrence in New Hampshire and, while not one of the most serious apple troubles, it often does considerable damage. It sometimes attacks the fruit, but its effects are usually confined to the foliage. Here it causes yellowish spots (Fig. 18) which usually become somewhat elevated in the center and in which are produced numerous spores. The spots usually appear on the leaves in June. The spores from these spots are borne by the wind and attack the twigs of Junipers, causing morbid growths or swellings. One of the most characteristic effects produced is the so-called "cedar apples" (Fig. 19). The fungus passes the winter on the Juniper and in the spring produces gelatinous outgrowths that contain numerous spores. These spores, when borne back to the apple foliage, produce the rust again, and thus the fungus passes from one host back to the other.

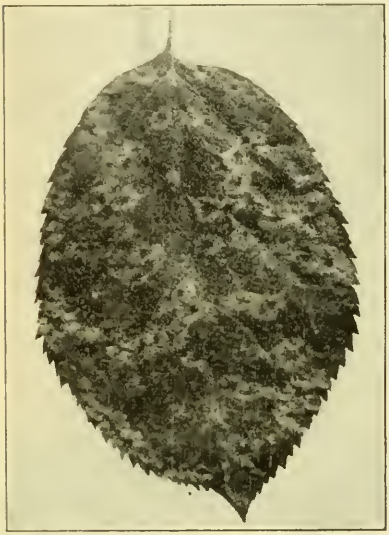


Fig. 18.—Rust on apple leaf.

Fig. 19.—Cedar Apple on red cedar.

Treatment. Spraying has not usually been very effective in controlling the disease. Since the Junipers harbor the fungus thru the winter the method of control is, obviously, to destroy them.

BLACK ROT, CANKER AND LEAF SPOT.

Sphæropsis Malorum Berk.

The three diseases given above have been found to be due to a single fungus, "*Sphæropsis Malorum.*" The black rot of the apple is very common in New Hampshire. It is dark brown or black in color and the affected tissue comparatively firm. It is thus readily distinguished from the soft rots. It may start on any part of the fruit, but often begins at the blossom and frequently follows insect stings. The disease is primarily a rot of ripe fruit, but it may often be found as dark brown spots 1-8 to 1-2 inch in diameter several weeks before the apples are mature. These spots may develop very slowly until about picking time, but after that spread rapidly, involving the whole apple. As the rot develops, numerous minute, black elevations may be seen on the apple (Fig. 20). These are the spore producing bodies of the fungus and are known as pycnidia. The rot does considerable damage in cellar storage, but is especially common on the fruit left on the trees or ground. This worthless fruit becomes a source of infection the following spring.

Fig. 20.—Black Rot of apple due to *Sphæropsis Malorum.*

Canker is a term applied to rough, unsightly wounds that are known to be due to the action of fungi. The most common variety of this trouble in New Hampshire is the "black rot canker," also known as the "New York apple tree canker."[1] Both large and small limbs are attacked and sometimes the trunk. In some cases it seems to cause merely a greater roughening of the bark, but where a broken twig or other injury furnishes an entrance to the actively growing tissue of the host the effects

[1] Paddock, Wendell. The New York Apple-Tree Canker. N. Y. Agr. Exp. Sta. Bull. 163. Paddock, Wendell, Ibid (Second Report), N. Y. Agr. Exp. Sta. Bull. 185.

are often much more pronounced. In serious cases the bark may be killed over considerable area and become conspicuously cracked and roughened (Fig. 21). It is set off from the living bark by a very definite boundary. Limbs are often so nearly girdled that the parts beyond die. Pycnida similar to those on the fruit are found on the canker.

Fig. 21.—Black Rot Canker.

Like the other diseases attributed to *Sphæropsis Malorum*, the leaf spot is of general occurrence in New Hampshire. The disease makes its appearance on the leaves shortly after they unfold from the bud. Infection continues thruout the spring, but notes taken the past two years indicate that it is uncommon after the middle of June. At first the spots are small, purple areas, but as growth progresses they become yellowish-brown in color and attain a diameter of from 1-8 to 1-2 inch (Fig. 22). They are quite uniformly circular in outline. The margins are somewhat elevated, giving to the spot a sunken appearance. As the spots become older a secondary growth may spread from the central affected area, producing a somewhat irregular blotch in which the outline of the original spot can always be recognized. (See Fig. 23.) It often happens that several of these areas become confluent, and thus the greater part of the leaf may become affected. Spotted leaves fall from the trees early in the fall and their working efficiency is always greatly reduced by the middle of the summer. (See Figs. 24

and 25.) Trees thus robbed of their foliage from year to year must eventually become greatly impaired in their vigor.

Fig. 22.—Early stage of Leaf Spot.

The cause of the leaf spot has occasioned no little difficulty. A number of fungi have been found to be present in the spots, but inoculation experiments have indicated that *Sphæropsis Malorum* is probably the only one that is of importance in the production of the disease.

Fig. 23.—Late stage of Leaf Spot, showing growth in the size of the spots.

Treatment. The fact that one fungus is responsible for three different forms of disease makes its destruction a matter of special importance and rather unusual difficulty. Spraying has been quite effective in controlling the leaf spot. In the summer of 1908 the per cent. of leaves spotted in the orchards referred to under apple scab was reduced from 97 to 26 by the use of Bordeaux and to 21 by the use of lime-sulfur solution. Five sprayings were made, but it is probable that only the first three were

effective for leaf spot. Sprayings made at various times in the summer have had little or no effect upon the number of spots of rot on the fruit at picking time. The destruction of the affected fruit seems to be the most efficient treatment for this form of disease. All cankered limbs should be cut out and burned. Large wounds should be protected by a covering of paint. Thoro spraying is of value in protecting the limbs. Heavy applications made when the trees are in a dormant condition are probably especially efficacious. (See page 32.)

Fig. 24.—Unsprayed tree defoliated by Leaf Spot.

BITTER ROT OF THE APPLE.

Glomerella rufomaculans (Berk.) Spauld & Von Sch.

The bitter rot fungus produces cankers on the limbs as well as a rot on the fruit. The rot develops much earlier in the year than the black rot, and the adjacent tissue of the apple has a bitter taste. In the South and the Central West the bitter rot is the most destructive apple disease. It is of very rare occurrence in New Hampshire, and it is probable that the climatic conditions will prevent it from ever becoming serious here.

FIRE BLIGHT.

Bacillus amylovorus (Burrill) De Toni.

This is a very serious disease of the pear. On the apple th disease may start in the blossom or in the tender tips of growing twigs and spread to kill the entire season's growth. Insects are the great agency in the spread of the disease. The trouble is of rare occurrence in New Hampshire, and has been seen by the writer only on trees that were closely adjacent to seriously

Fig. 25.—Sprayed tree adjacent to the one shown in Fig. 24.

affected pear trees. The destruction of affected limbs is the only remedy.

CROWN GALL.

Pseudomonas tumefaciens. Erw. Smith and Townsend.

Crown gall is the term applied to abnormal outgrowths near the surface of the soil in the region of the collar (Fig. 26). It occurs on practically all the stone, pomaceous and bush fruits. With most of these plants the disease has been proven to be

Fig. 26.—Crown Gall on Apple.

uted in America. It is not of so common occurrence in New Hampshire as the black rot canker, but is more destructive where found. The fungus seems to be dependent upon wounds for entrance to the host tissue. It attacks the inner bark and the cambium, and to some extent the young wood. The mycelium is perennial in the host. As the new growth develops around the wound it is attacked and killed by the fungus; thus a series of ridges may be developed, giving a characteristic appearance to the disease (Fig. 27).

Two kinds of summer spores are contagious. Great care should be taken to reject all diseased plants at the time of transplanting. The disease usually does the greatest damage on nursery stock.

EUROPEAN APPLE CANKER.

Nectria ditissima Tul.

This disease is reported as serious in the orchards of Europe, and is apparently becoming distribu-

Fig. 27.—European Apple Canker.

produced, the first small and unicellular, the second sickle-shaped and having three or more cells. The latter are probably largely responsible for the spread of the disease during the summer. In the spring compact clusters of red lemon-shaped perithecia may be found near the edge of the canker. These may be seen with the unaided eye. They contain numerous two-celled spores borne in asci or sacs.

Treatment. All cankered limbs should be destroyed. Wounds should be thoroly coated with paint. Spraying may serve to disinfect the smaller wounds produced by insects, hail storms, etc. (See page 32.)

Fig. 28.—Blister Canker of apple. The bark has been removed from the upper portion showing the circular markings produced in the wood.

BLISTER CANKER.

Nummularia discreta Tul.

The disease is sometimes known as "Illinois Canker," since it was first observed as particularly destructive in that state. It seems to be less destructive in New Hampshire than the black rot and European cankers. It has a characteristic appearance that readily distinguishes it from either of these diseases. (See Fig. 28.) It is usually found on the larger limbs, and sometimes attacks the trunk. Old cankers are often a foot or more in length. The fungus attacks the wood as well as the bark. In the early stages of the disease the bark is brown and slightly sunken and usually set off from the healthy bark by a distinct boundary. As the season advances circular fungous masses known as stromata develop on the diseased area. They are

formed beneath the bark, but soon break through to the surface, furnishing the most characteristic feature of the disease. The stromata are firmly fastened to the wood by means of a hard ring of fungous tissue, so that they remain attached to it even after the bark has fallen away. Summer spores are produced on the surface of the stroma. Later in the season, numerous flask-shaped perithecia are formed within the stroma, but opening on its surface. These produce many club-shaped asci, each containing eight spherical, brown spores.

Treatment. The fungus seems to be dependent upon wounds for entrance to the host tissue. The best method of treatment is found in avoiding unnecessary injuries to the tree and in the proper care of all wounds. All cankered limbs should be destroyed.

WINTER INJURY.

The winter of 1906–1907 caused very serious injury in the orchards of New Hampshire. The damage was especially great in young orchards and in those situated on low ground. Many trees were found to be entirely dead the next spring and others had only sufficient vitality to put forth leaves on a few scattering limbs. As the summer advanced it was evident that many trees that had appeared fairly vigorous early in the spring had sustained serious injury, and leaves on one large limb after another would wither and turn brown. Thruout the summer of 1907, and even in that of 1908, trees continued to succumb to the injuries received in the above mentioned winter.

Upon examination of the injured limbs and trees it was found that the cambium and the inner bark had been dead over large areas from the beginning of the season. Such injuries sometimes amounted to practically a girdling of the limb or trunk and the portions beyond were soon starved. In other cases, where the girdling was not so complete, the tree survived for several months, and in some cases seemed to outgrow the effects of the injury. As the summer of 1907 advanced, sunken dead areas became quite common on the injured but living trees. The living tissue at the margin of these dead patches made a very unusual growth, pushing out over the injury and developing a marked ridge around it, thus leaving it as a conspicuously depressed area.

Fig 29.—Winter Injury on a young apple tree.

The line between the living and the dead bark was often marked by an open crack (Fig. 29).

Various varieties of trees suffered from winter injury. The Baldwin seemed to be more susceptible than any other variety of apple. Considering the severity of the winters in New Hampshire it seems doubtful whether the Baldwin should be as universally used in orchards as it has been in the past.

Cause of Winter Injury. The winter of 1906–1907 was an unusually cold one and the low temperature might be regarded as sufficient explanation for the serious results. Injury from cold in plants, however, is largely dependent upon the condition of the cells exposed. The fall of 1906 was characterized by the frequency of showers and unusually high temperatures. As a result of this, growth continued late in the season and the trees must have gone into the winter without the usual reduction in amount of water, and with the wood not completely matured. This would be especially true of vigorous growing varieties like the Baldwin, and of trees situated on low ground and in poorly drained soil. The apple crop of 1906 was large and the vitality of the trees thus greatly reduced. This weakening from overproduction was probably also partly responsible for the injuries of the following winter.

Treatment. The great lesson to be learned from the winter injuries that have occurred in the state is that of the importance of air and soil drainage in the selection of an orchard site. Injured trees have usually been benefited by rather severe pruning. The general occurrence of canker fungi in the state makes the treatment of the injured areas of special importance. Like all other wounds, they should be covered with wax or coated with paint or Bordeaux.

SPRAY INJURY.

Injury from Bordeaux mixture is of quite common occurrence in New Hampshire. On the leaves it appears first as purplish brown spots of various shapes and sizes. They are usually smaller, more irregular in shape and more thickly distributed on the affected foliage than the leaf spot previously described. Soon after the appearance of these spots the leaves may begin to turn yellow. Leaves so affected soon fall, and in serious cases the trees may be almost entirely defoliated. Such extreme cases, however, have been very rare.

On the fruit the injury appears first as small, black or brown specks scattered thickly over the apple. Later in the season the skin may become corky and russeted. In serious cases the apple may be much roughened and deformed, and large, deeply-sunken scars develop (Fig. 30). The slightly affected fruit

may almost entirely outgrow its injuries by picking time, but when the injury is very great the fruit may drop before maturity, and in any case is of little commercial value.

The most serious injuries have been obtained from the early sprayings. This may be largely due to the fact that showers are common at that time of year. It is a well-known fact that when an application of Bordeaux is followed by rain within the next few days it is likely to produce injury. Records from a large number of cases of Bordeaux injury in New Hampshire would

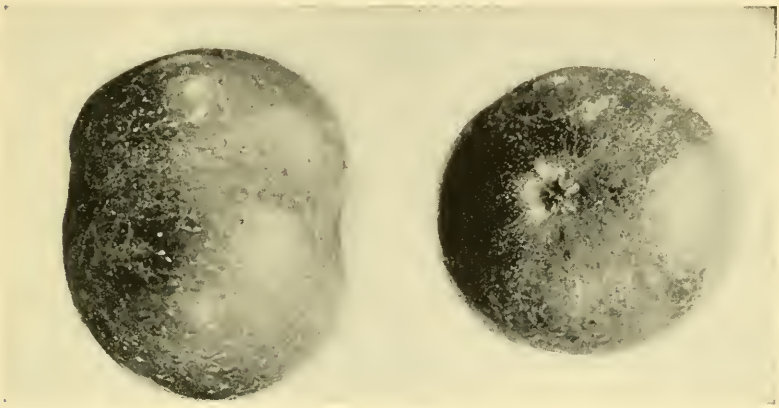
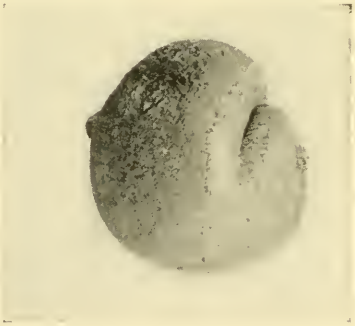


Fig. 30.—Baldwin apples russeted with Bordeaux mixture in 1906.



indicate that damage seldom, if ever, occurs in properly sprayed orchards except under the above mentioned conditions.

The injury done by Bordeaux has not been great enough to offset the good accomplished, and various commercial growers have annually obtained large profits from its use, yet the condition has been serious enough to make strong demands for a solution of the difficulties. The matter has been taken up at various experiment stations, including

those of New York,[1] Illinois[2] and New Hampshire, but a complete solution of the problem has not been found.

Much trouble may arise from the use of improper mixtures and from unsatisfactory methods of application. Only good material should be used, and the following of the directions for making the solution is important. The foliage must be thoroly covered, but dripping from the leaves indicates an excessive or careless application. The nozzles should be of a kind adapted to give a very fine spray. Nozzles that give good results with insecticides may be entirely unsuited for Bordeaux. The Mistry and Friend's nozzles have given good results. The liquid should be applied to the tree as a fine mist and never allowed to sprinkle or drip from the nozzles. Mistakes are often made by trying to spray with insufficient power. A pressure of 70 pounds is essential, and one of 100 pounds or over is very desirable.

In looking for a solution of the problem various kinds and strengths of Bordeaux have been tested. While weaker solutions may produce less injury, they do not obviate the trouble. The use of an excess of lime has had little or no effect upon the amount of injury. The 3-3-50 formula seems to produce as little injury as any, and is most satisfactory for the majority of apple diseases. The patent Bordeauxs which are on the market have not been shown to be any less liable to produce injury than the home-made mixtures, amd many of them have proven quite inefficient in controlling diseases.

During recent years lime-sulfur solutions have been rapidly gaining favor as fungicides. They seem to be almost as effective as Bordeaux in controlling diseases and to be less likely to cause injury. In the summer of 1909 commercial, home-made and self-boiled lime-sulfur were used alongside patent and home-made Bordeaux in the orchards mentioned in the discussion of apple scab. None of the sulfur mixtures caused injury, while none of the Bordeauxs failed to do so. Recent experiments in other states have shown that when sprayings are followed by excessively hot dry weather the lime-sulfur is more likely to cause injury than Bordeaux. Probably the strongest argument against the use of lime-sulfur in New England is that it is very soluble in water and in rainy seasons more frequent applications are likely to be required to secure the same efficiency as obtained with Bordeaux.

[1] Hedrick, N. P. Bordeaux Injury. N. Y. Agr. Exp. Sta. Bull. 287. 1907.
[2] Crandall, C. S. Bordeaux Mixture. Ill. Agr. Exp Sta. Bull. 135. 1909.

FUNGICIDES.

Bordeaux. No other fungicide is so widely used as Bordeaux and no other has been proven so efficient in controlling diseases. It is prepared by combining solutions of copper sulfate or bluestone and lime. The solution most satisfactory for use in the apple orchard consists of:

Copper sulfate,	3 lbs.
Stone lime,	3 lbs.
Water,	50 gals.

This is known as the 3-3-50 formula. In a 3-4-50 formula, 3 pounds of copper sulfate and 4 pounds of lime are used to each 50 gallons of water.

The copper sulfate can be readily dissolved in hot water. If several hours are to intervene before it is needed for use, it is conveniently dissolved by placing in a sack and suspending in cold water in a barrel or other *wooden* vessel. As a matter of convenience the number of gallons of water used should be the same as the number of pounds of copper sulfate to be dissolved.

The lime should be slowly slaked in another vessel. Hot water insures a more complete slaking, but it is not essential. For the sake of convenience the lime milk may be diluted so that it makes as many gallons of solution as there were pounds of lime. A gallon of either solution should now contain a pound of the substance dissolved. These strong solutions should not be poured together, but should serve as stock solutions, and if properly protected from evaporation may be kept for several weeks or even the entire season.

To make a barrel of 3-3-50 Bordeaux, three gallons of the stock copper sulfate should be diluted to 25 gallons, and in another vessel three gallons of the lime milk similarly diluted. The two solutions may now be poured together, stirring constantly. If more convenient all of the dilution may be made with the lime and the strong copper sulfate solution then added to the extremely dilute lime. It is essential, however, that the solutions be diluted before they are combined. The resulting solution should have a large excess of lime, but if there is any question as to the purity of the lime, or, if a safeguard against mistakes is desired, the mixture should be tested for excess

copper by the addition of a few drops of potassium ferrocyanide solution. If there is an excess of copper sulfate present a conspicuous brown precipitate will be formed. In such a case more of the lime solution should be added. The absence of this precipitate indicates that the amount of lime already added has been sufficient to combine with all of the copper sulfate.

It has frequently been advised that Bordeaux should not be used after standing overnight, since when the precipitate has once thoroly settled it can never be got into as fine a state of division again. While the physical condition of old Bordeaux is not all that could be desired, it is far better than that of the average patent mixture, and if the difficulty of frequent preparation prevents the use of home-made Bordeaux the depreciation with age should not be too greatly emphasized.

Lime-Sulfur. The importance of lime-sulfur as an insecticide and its growing favor as a fungicide have caused considerable attention to be given to its preparation in recent years. The following is a very satisfactory formula: 50 pounds best stone lime, 100 pounds sulfur, water enough to make 50 gallons of solution at finish. The quantities may be proportionately reduced as desired.

Place the fresh stone lime in a kettle or other vessel to be used and slake slowly. Put in the sulfur, mixing it thoroly with the slaked or slaking lime, adding enough water to maintain a thin paste. Any lumps of sulfur or lime should be thoroly broken up. When slaking and mixing are completed the solution may be diluted to 50 gallons. Boil for about one hour, with occasional stirring. If the boiling has been sufficient, the sulfur will have entirely gone into solution, having combined with the lime to form a clear reddish-yellow compound. Enough water should be added to replace that lost in boiling, bringing the quantity of the solution to 50 gallons again. The solution is now ready to be diluted for use. For summer application on the apple orchard each gallon of this lime-sulfur should be diluted to 25 or 30 gallons.

Prepared lime-sulfur mixtures can be obtained on the market. A number of companies are selling a good product, and the commercial lime-sulfur has much more in its favor both as to quality and price than the patent Bordeaux. It is usually stronger than that obtained by the above method of preparation

and should be diluted at the rate of 1 gallon to 30 or 35 for summer use. Some have reported satisfactory results with a dilution of 1 to 100, but the writer's observations do not lead him to believe that this strength will hold the diseases in check when they are at all serious.

It is very desirable that a hydrometer, or specific gravity bulb be used in making dilutions of lime-sulfur. If an instrument[1] having a scale reading from 1.000 to 1.35 is obtained, it may be used for testing the strength of both the concentrated and the diluted solutions. Solutions having a specific gravity of 1.015 (2.14 Baume) have been repeatedly used in New Hampshire orchards without injury to the foliage or fruit, but 1.010 (1.44 Baume) solutions have controlled the apple scab and other diseases almost as well as the stronger mixture. When the specific gravity of the stock solution is found the number of dilutions is readily determined by dividing the decimal of the concentrate by the decimal of the spray desired. If the concentrated solution should have a specific gravity of 1.24 (28.06 Baume), the number of dilutions may be determined by dividing .24 by .010, giving 24. To obtain a solution having a specific gravity of 1.010 the stock solution must therefore be diluted to 24 times its own volume. Likewise a stock solution having a specific gravity of 1.30 (33.46 Baume) must be diluted to 30 times its own volume to obtain a solution having a specific gravity of 1.010.

Stock solutions of lime-sulfur may be prevented from crystallizing on the exposed surface by covering them with a thin layer of oil to exclude the air. Any lime residue left as a sediment in the stock solution favors crystallization.

As an insecticide with lime-sulfur arsenate of lead should be used.

Self-Boiled Lime-Sulfur.—A self-boiled lime-sulfur recommended by Scott[2] has given good results in New Hampshire orchards. The heat for combining the lime and sulfur is obtained from the slaking lime. The mixture should never be made in small quantities, as under such circumstances the loss of heat is too great. It may be prepared as follows:

Place 20 pounds of good stone lime in a barrel and pour 3 or

[1] Can be obtained from George D. Feidt & Co., Philadelphia, or Eimer & Amend, New York City.

[2] Scott, W. M. Self-Boiled Lime-Sulfur Mixture as a Promising Fungicide. U. S. Dept. Agr. Bur. of Plant Industry. Circular 1. 1908.

4 gallons of water (not heated) over it. Add 20 pounds of sulfur and 3 or 4 gallons more of water. Mix the sulfur and slaking lime thoroly, crushing any lumps of sulfur and adding more water if the mixture becomes too thick to stir. The heat from the slaking lime will boil the mixture violently. A piece of carpet thrown over the top of the barrel helps to keep the heat in and thus to prolong the action. When the boiling ceases the mixture is ready to dilute. The above quantity should be diluted to 100 gallons for use on apple foliage. If hot water is used in preparing the mixture a greater dilution is necessary.

The self-boiled lime-sulfur seems to offer as little opportunity for spray injury as any fungicide. Its value in controlling diseases will depend upon the quality of lime used and the care in making. Lime that is partially air slaked is unfit for use in the preparation of any fungicide, but is especially inefficient in making the self-boiled lime-sulfur.

SPRAYING FOR APPLE DISEASES.

No.	Application.	Fungicide.	Purpose.
1	Before buds open.	Bordeaux 6-6-50 or copper-sulfate 1-25 or lime-sulfur 1 to 11. Lime-sulfur should be used in orchards having San José Scale.	Gives antiseptic treatment to any small wounds not otherwise cared for. Destroys any spores of scab, leaf spot, etc., that may have reached the tree by this time.
2	After leaves expand and before flower buds open.	Lime-sulfur 1½-50 or Bordeaux 3-3-50.	For apple scab. Most important application for leaf spot.
3	When flower buds have mostly fallen.	Lime-sulfur 1½-50 or Bordeaux 3-3-50. An insecticide should be added for the codling moth.	Most important application for apple scab.
4	Three weeks after third application.	Lime-sulfur 1½-50 or Bordeaux 3-3-50. An insecticide should be added for the codling moth.	For apple scab and fruit spot.
5	Two or three weeks after 4.	Lime-sulfur 1½-50 or Bordeaux 3-3-50.	For fruit spot. May be omitted if earlier sprayings have been made.
6	First or second week in August.	Lime-sulfur 1½-50 or Bordeaux 3-3-50. An insecticide may be added for the brown-tail moth.	To prevent late spread of apple scab.

The relative importance of the different applications outlined above must be determined by the seriousness of the different diseases. Application No. 3 should never be omitted. Use arsenate of lead as an insecticide with lime-sulfur.

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