
New York Agricultural Experiment Station.

GENEVA, N. Y.

CORK, DROUTH SPOT AND RELATED DISEASES OF THE APPLE.

A. J. MIX.



PUBLISHED BY THE DEPARTMENT OF AGRICULTURE.

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A. J. MIX.

SUMMARY.

Two little-known apple diseases are found in the Champlain valley. These are perhaps only different types of the same disease, are non-parasitic in nature, and are apparently closely related to the well known fruit-pit or stippen disease. The names cork and drouth spot are proposed for them. Associated with the drouth spot are abnormal conditions of the twigs and foliage; it is proposed to call these drouth die-back, and drouth rosette.

Cork is also found in Ontario and in New South Wales. It affects chiefly the Fameuse variety. Apparently the drouth spot has occurred in Maine and Virginia; and a closely related trouble occurs in the Pacific Northwest. Rosette has been reported from Colorado, California and Idaho; and both the rosette and die-back from the irrigated sections of Washington and Oregon. In the Champlain valley certain orchards and even individual trees are more affected than others. It is only in these particular cases that the diseases assume economic importance.

Cork is evident in late June as dead brown spots beneath the skin of the fruit or around the core. The fruit is normal externally. Later the fruit becomes distorted and knobby, and brown corky areas are found scattered throughout the flesh. Drouth spot occurs in early June and fresh stages may develop throughout the summer if the weather continues dry. Superficial or sunken, irregular, dead, brown spots show in the skin of the fruit, and dead brown areas may occur in the flesh beneath. In late stages the apple becomes cracked and deformed. The internal spots of both diseases are in close proximity to branches of the vascular system, and superficial drouth spots often show a wavy pattern of wrinkles apparently marking the subepidermal vascular network.

Under the microscope these spots show cells with brown amorphous contents shrunk away from the walls. Sometimes the cells are collapsed.

Die-back consists in the death of a portion of the twig from the tip backward. Beyond this a brown discoloration in the cambial region extends back into healthy wood. The dead twig may be replaced by a healthy lateral from the base; but often there is found near the base of the twig a rosette-like cluster of dwarfed, lanceolate leaves. This appearance and one in which a compact cluster of similarly dwarfed leaves crowns a long, bare twig have been included under the name rosette.

Field observations show that these diseases may occur on the best types of soil in the locality, under conditions of careful culture, and in young and vigorous trees. In certain cases a shallow soil seems connected with their development. They may appear, however, on deep soils of good physical condition. A condition of soil conducive to poor moisture supply seems connected with severe outbreaks. Drouth accompanied by high, dry winds seems to bring on a large amount of drouth spot and cork; a subsequent rainy period, as in 1915, causes them to disappear. In a rainy spring, as in 1916, some disease occurs in trees that have been previously affected, but the amount is inconsiderable and the period of development much shortened.

The initial stage of die-back is found on the season's growth in midsummer. The following spring this die-back and the accompanying rosette are very noticeable. Dry weather in late summer seems directly responsible for die-back of the season's growth. If a wet summer follows a dry spring, this die-back is practically absent, and there is evident recovery from its preliminary stages. No abnormal condition of the roots is necessary to the occurrence of die-back and rosette.

Since these diseases may appear, to a limited extent, in a rainy season, lack of soil moisture cannot be considered their sole cause. It is, however, the one predisposing factor. Other factors, yet unknown, may be operative.

Assuming that an insufficient moisture supply to the fruit, accompanied by great transpiration, may bring about these diseases, it is suggested that the exact method of their occurrence may be through the leaves robbing the fruit of water. Leaves have a higher cell-sap concentration than green fruits and can remove water from the fruits by the process of osmosis. Chandler has called attention to this fact, and demonstrated it with detached

twigs bearing fruits and leaves. Following Chandler's method fruits have been rapidly wilted, and then, by placing the twigs in water, caused to regain their original state of turgor. In many such fruits spots resembling those of drouth spot, and, occasionally, those of cork, were produced.

One experiment indicated that a reduction of the leaf surface of the tree during the critical period might prevent the drouth spot, but this is not suggested as a practical means of control.

The only control method which offers promise of results is one looking to conservation of soil moisture, and an even distribution of the moisture supply throughout the season. Clean cultivation is not sufficient. From certain suggestions of benefit in the Champlain valley, and from results secured in the Pacific Northwest, clean cultivation followed by a leguminous cover crop, or the planting of a leguminous crop such as alfalfa in the orchard, seem methods which should be tried. Certain growers in the Champlain valley are testing them.

INTRODUCTION.

During the summer seasons of the years 1913-1916, inclusive, the writer had opportunity to observe two little-known apple diseases. The observations were made in Clinton County, New York, in the apple-growing section of the Champlain valley.

These two diseases are believed to be essentially the same, and closely related to the common apple disease known as fruit-pit, bitter-pit, or stippen. They have been called cork and drouth spot respectively. Cork is a name which has been applied locally for a number of years; drouth spot has been selected as a name indicating the probable cause. Two disorders of the twigs and foliage associated with the drouth spot have been called drouth die-back and drouth rosette.

VARIETIES AFFECTED.

Cork affects chiefly the Fameuse variety, although it sometimes occurs in Northern Spy, and has been found, rarely, in Oldenburg and Ben Davis. Drouth spot has been observed by the writer on the following varieties: McIntosh, Northern Spy, Ben Davis, Esopus, Bellflower, Maiden Blush, Wolf River, Wealthy, Baldwin, Jonathan and two unidentified varieties. The only variety of commercial

importance in the Champlain valley not included in the above list is Rhode Island. The disease has never been observed on Tolman, but this variety is less extensively grown.

HISTORY AND DISTRIBUTION.

Cork has apparently been known locally for at least fifty years. There is, however, little mention of it in literature, at least in a way which would allow it to be distinguished from the true fruit-pit or stippen. Craig (8) notes Fameuse as susceptible to stippen or "dry rot," as he terms it, and from the description by Selby (21) of specimens of Fameuse which he had received from Craig it is apparent that here was a case of typical cork. Selby (22), in a discussion of "brown spot" or "dry rot" of Baldwin, mentions internal spotting as occurring without external lesions in the varieties Fameuse and Northern Spy. Cobb (7) describes an "obscure disease" of the apple occurring in New South Wales. McAlpine (13) states that he visited this locality in the season of 1912 and found the same disease in various orchards. It was confined to the variety Pomme de Neige (Fameuse). The same author (14) again mentions this disease, stating that it is a type of bitter-pit occurring when the apples are very small, the irregular knotty appearance being due to subsequent growth. His figures, as well as those of Cobb, show that the "obscure disease" is identical with the cork of Fameuse as found in the Champlain valley.

Drouth spot, so far as is known to the writer, had not been mentioned in literature prior to his first observations in Clinton county. Specimens were submitted in 1913 and again in 1914 to Dr. Charles Brooks, of the Bureau of Plant Industry, and in 1914 Dr. Brooks visited Clinton county and went over the situation with the writer. He stated that he had never observed the trouble, although he had seen somewhat similar troubles in the irrigated sections of the Pacific Northwest. Dr. W. J. Morse, of the Maine Agricultural Experiment Station, who saw specimens of the disease in July, 1914, expressed the opinion that he had seen apples similarly affected in Maine. Recently, Reed and Crabill (20) have described a "skin crack" of the York Imperial in Virginia. The writer is convinced that this was a case of drouth spot that was not observed until in a late stage ("early in September"). It is mentioned as prevalent in 1914 and as having been noticed previously only in

very dry seasons. Brooks and Fisher (3), under the heading "corky pit or drouth spot," describe an apple disease occurring in the Northwest which, if not identical with the drouth spot, is at least very similar to it. They also state: "There is another form of corky pit that occurs on shallow soils in some sections of the East and West. It is common where there is a hardpan at a slight depth and also where there are peculiar soils outcropping. This disease is quite generally associated with rosette." The writer believes that the trouble occurring in Clinton County is referred to in the above statement.

Allen (1), in a report on the study of the root condition of apple trees in the Hood River valley, makes the following statement: "Some trees were found to be so seriously devitalized by drouth and starvation that the fruit was not only badly pitted but hollow in places. On such trees the foliage was very small; a large portion of it had fallen; and the ends of many twigs had begun to die back." The illustration of a pitted apple accompanying this article is more suggestive of certain severe types of drouth spot than it is of true fruit-pit or stippen. Also, it seems probable that the die-back here referred to may be the drouth die-back occurring in the East.

Apple tree rosette was first described by Paddock (19) from Colorado in 1902. Apparently, the same trouble had been noticed in California by Loughridge (12), where the cause assigned was an excess of alkali in the soil. Paddock presented evidence against this cause and ascribed the trouble to winter injury. Judson (11) states that, in 1903, apple rosette occurred in several parts of Idaho. It failed to appear on whip grafts made from affected trees. Henderson (10) describes the same trouble in Idaho under the heading "apple twig blight."

Rosette occurs in Washington and some work is apparently being done on the problem, for Cardiff (4) reports progress up to 1915 on "winter desiccation of fruit trees," or rosette. Photographs of trees affected with rosette accompany this article. The trouble is said to be independent of an excess of soil alkali, and to exist only in soils in which the humus content is very low. It is not transmitted by grafting from diseased onto healthy wood.

Clawson (6) says: "Rosette has caused a great loss to the orchardist of this [Wenatchee, Washington] as well as other districts of the Northwest."

Unfortunately, from the little that has been published regarding the rosette of the Pacific Northwest it is impossible to say positively that it is the same as that occurring in association with the drouth spot of the Champlain valley; but from conversation with Dr. Charles Brooks, of the Bureau of Plant Industry, who has seen both troubles, and from the examination of Cardiff's figures, and of photographs submitted to the Department of Plant Pathology at Cornell University by O. M. Morris, Horticulturist of the Washington State Experiment Station, the writer believes that they are identical.

How long the drouth spot has been known in the Champlain valley is uncertain. In 1913 two growers stated that they had observed a few apples affected with the disease about six years before and at various times since. A third grower stated that the trouble had occurred in his orchard several years previously and that at the same time the trees were badly affected with "tip blight." This may have been the drouth die-back to be described later.

The drouth spot occurred to a very slight extent in 1913, was prevalent throughout the season of 1914, and in 1915 was abundant early but disappeared after the beginning of the rainy period in July and August. In 1916, which was a very rainy season, the disease was much less prevalent. It occurred to a limited extent in one orchard, and in a few trees in other orchards. In all these cases the trees had been badly diseased in the past. The greater part of the trees which had borne diseased fruit in past years were entirely free from the disease in 1916.

ECONOMIC IMPORTANCE.

Whether it drops from the tree, as in drouth spot occurring early, or persists and becomes deformed, as in cork and late appearing drouth spot, an affected fruit becomes a total loss. Cork usually takes the whole crop of affected trees or of individual branches year after year. In some cases, in favorable years, it has been known to affect the entire Fameuse crop of some orchards. Drouth spot may involve only a few fruits on an affected tree, or may, in some cases, ruin its entire crop. In one orchard, in 1914, it was estimated that the loss from drouth spot was two hundred barrels. Eleven hundred were actually harvested. This, however, is extreme.

At present, these diseases cannot be said to be of great economic importance. They have been serious in comparatively few orchards. The apple-growing area in the Champlain valley is somewhat restricted at present, but is gradually being extended. With the growth of the industry in that locality these diseases may assume considerable importance.

SYMPTOMS.

FRUIT-PIT, BITTER-PIT OR STIPPEN.

The fruit-pit of apples is described by Brooks (2) as follows: "In the early stages of fruit-pit one finds numerous sunken areas from two to six millimeters in diameter on the surface of the apple. These depressions are somewhat hemispherical in shape and have the appearance of bruises. At this stage the spots are not brown and often show no difference in color from the surrounding surface of the apple. They may be a deeper red than the adjacent tissue when occurring on the colored portion of the apple and a darker green when on the lighter parts. Later they begin to take on a brown tint, but at first this seems to show through from rather deeply seated tissue and not to arise from any discoloration of the epidermal or immediately underlying cells. Sections of such spots show that this is the case, and that the browning and shrinking of the cells occur in the pulp of the fruit and in the tissue that is transitional between it and the hypodermal parenchyma. Later the surface cells also become dark brown. The epidermis may be smooth and apparently unbroken in both early and late stages. As the disease advances spots situated near each other often become confluent, developing into one large spot. In all such cases examined it was found that the original spots were closely connected with one vascular branch. The writer has been unable to detect a bitter taste in the browned tissue of the fruit pits.

"*Internal browning of tissue.* The surface spotting is often accompanied by browning of the tissue immediately surrounding the vascular bundles. Upon cutting such an apple one sees numerous apparently isolated brown spots. Further study shows that these are not isolated but are in reality continuous strands of brown tissue surrounding the vascular bundles. The portion of the vascular system that is most commonly affected is that lying within fifteen

millimeters of the surface of the apple. The surface spots often occur without the internal browning and also the internal browning may occur unaccompanied by any surface derangement."

CORK.

Cork is most commonly observed when the apple is in a state anywhere from half grown to nearly mature. It may be briefly characterized as internal browning described by Brooks in the preceding paragraph, without external pits, but with the surface of the apple thrown into a series of elevations and depressions. A large number of brown corky areas occur throughout the flesh, following closely the course of the vascular bundles. In no case do these extend outward as far as the skin, consequently there are none of the external brown pits characteristic of true fruit-pit or stippen. A further difference from the usual type of fruit-pit is that the spots are not more abundant in the peripheral zone, but are scattered throughout the flesh of the fruit. There is no bitter taste connected with this disease in Fameuse apples.

In the earliest observed stage of the disease, when the fruits are about two centimeters in transverse diameter, there is no external evidence of an abnormal condition. The shape of the fruit and the color and appearance of the skin are normal. Upon cutting open the fruits, comparatively large, brown, corky areas are seen at various places in the flesh.* These are often near the periphery directly opposite one of the main vasculars (Plate I, fig. 1); or they may be, in some cases, arranged irregularly within the core lines around the core. Sometimes, in the earliest stage of the disease, the internal brown spots are surrounded by a green water-soaked area suggestive of the well known water-core disease. This area may even show through the skin of the fruit as a darker green

* There has been, locally, some confusion between cork and the injury caused by the apple maggot, or railroad worm (*Rhagoletis pomonella* Walsh.). This confusion is the more excusable since, next to Tolman, Fameuse is the variety most attacked by the apple maggot. There should, however, be no difficulty in distinguishing between the two. Apple maggot injury is first observed in July. The apple is smooth externally. Often a small, dark colored spot shows in the skin around the egg puncture. When cut across, the flesh is seen to be traversed by irregular, yellow-brown streaks which have a water-soaked appearance. In cork, the spots are more regular, definitely outlined, and dry and spongy. In late stages of apple maggot injury the whole apple becomes honeycombed with the feeding tunnels of the maggots and the flesh is reduced to a brown, spongy mass held together by the skin of the fruit. A corky apple never reaches this state of disintegration. Its flesh remains firm.

water-soaked spot. This appearance is not, however, characteristic of the disease and is not found in later stages.

DROUTH SPOT.

The lesions of drouth spot may be divided into two general types, —superficial and deep seated. They also vary somewhat according to the age and size of the fruit when affected, and the age of the lesion.

Superficial lesion.—In this case an early stage of the disease is manifested by an irregular, light-brown area in the skin. When the fruits affected are large, two or three centimeters in transverse diameter, the surface of the fruit is usually smooth and regular, there is no shrinkage or sinking in, nor any abnormality in the flesh beneath. On large fruits, also, the lesion occurs often on the cheek of the fruit and is not more common toward the calyx end. When the fruits are smaller, and sometimes on larger fruits, the spots show an irregular, wavy pattern, formed by a series of wrinkles or corrugations, the elevations and depressions of which are, however, very small, and it is rare that there is any abnormality in the flesh of the apple. It is as though the browned areas marked the course of the fine network of vascular endings situated just beneath the skin of the fruit. [See McAlpine (13) and Brooks (2)]. This idea receives confirmation from a study of cross sections through such lesions placed under the microscope. (See page 486.) On young fruits, also, the disease occurs normally toward the calyx end of the fruit, often as a broad collar of diseased tissue just below the base of the calyx lobes. Plate II, fig. 1, shows superficial lesions on young fruits.

When the spot first appears tiny drops of a clear or yellowish gummy exudate may occur on its surface. Under the microscope this exudate shows as a clear gum. No organism is found associated with it. It is considered to be merely an expression of cell sap from the diseased hypodermal cells.

Most of the fruits affected when young drop from the tree. Some of them (and this is the rule with fruits which have grown large before becoming diseased) persist, and as they grow the affected area becomes roughened and cracked. Often deep seated cracks are formed. This, of course, is not essentially different from the cracking which occurs whenever a portion of the skin of the

fruit is killed through any cause (as, for instance, a severe attack of apple scab) and the fruit makes subsequent growth.

Deep-seated lesion.—This type of lesion is characterized by the presence of brown, corky areas in the flesh of the apple and by a sinking in of portions of the epidermis. On young fruits, from one to two or two and one-half centimeters in transverse diameter, the disease appears as a large brownish area in the skin of the fruit, usually near the blossom end, which is irregularly sunken and wrinkled, indicating shrinkage of the tissues beneath. Cross sections show brown areas in the flesh near the periphery. These are opposite the main vasculars, and often in the center of one of them there is a large cavity, the apex of which reaches one of these vessels. (Occasionally, apples are found in which there is one of these corky areas or cavities opposite each of the ten main vasculars.) These internal spots are often connected by a narrow brown streak running close to the periphery of the apple. Sometimes these streaks do not connect, but extend only a short distance in either direction from the central spot. The shrinkage of the skin over a considerable area, and the presence of these brown corky spots and streaks in the periphery suggest the type of fruit-pit described by McAlpine (13) as “confluent bitter pit” or “crinkle.” * Plate II, fig. 2 shows in surface view and Plate III, fig. 1 in cross section, deep-seated lesions as occurring on young fruits.

The above type of lesion was very common on the smaller fruits in the spring of 1915, almost to the exclusion of any other type.

On larger apples, three centimeters or more in diameter, the deep-seated lesions, if occurring, are smaller in extent, and appear as brown or purple sunken spots with brown, corky tissue beneath. Most common on these larger fruits is the superficial spot described above. Plate III, fig. 2 shows some types of spots occurring on large fruits, also the cracking of the skin due to subsequent growth.

* McAlpine's description of the symptoms of “confluent bitter pit” is as follows: “When the disease is fully developed the crown end of the apple is thrown into very irregular folds and prominent ridges There may be only a slight irregularity toward one side of the crown, or it may sometimes be deeply sunken but still firm sometimes the irregularity may extend toward the base when a section is made through the crinkled portion, then the appearance of the disease is very characteristic. The green skin is quite intact, but immediately beneath it there is a more or less interrupted ring of brown tissue, with large cavities here and there owing to the rupture of the tissue. When a longitudinal section is made it may be confined to the crown end, or it may extend almost to the stalk.”

Variation of lesions.—Peculiar variations from the above-described appearances sometimes occur. Such are: (1) Small red pits near the calyx end of the fruit, found on the Bellflower variety; (2) raised red blisters or pimples, occasionally appearing on Fameuse.

There is no bitter taste, such as has been ascribed to fruit-pit, in an apple affected with drouth spot; but it is insipid, and distinctly lacking in acidity. This may be noticed even in very young green apples, and sometimes in healthy fruits growing on diseased trees.

DIE-BACK AND ROSETTE.

On April 28, 1914, in orchard No. 1 (in the section where the drouth spot had occurred the previous summer), a few trees were noticed with twigs which were not putting out foliage. It was believed at the time that the ends of these twigs had winterkilled and no attention was paid to them beyond preserving material for microscopic examination. As will become evident later, this was, no doubt, die-back originating the previous summer. Some of these twigs died back during the summer of 1914. Others remained alive, but made no growth, their upper buds continuing dormant throughout the summer. Some of the lower buds on these twigs developed clusters of very small, lanceolate leaves with shortened petioles. In some cases the twigs made a very short terminal growth, resulting in a thickened, shortened axis an inch or so long, bearing a cluster of leaves, some normal and some short lanceolate, the general effect being that of a long bare twig capped by a rosette of leaves. This last-mentioned appearance was pronounced by Dr. Charles Brooks to be very similar to the so-called rosette occurring in the irrigated orchards of the Pacific Northwest.

Paddock (19) describes apple-tree rosette as follows: "Some of the trees are dying, while there are a number of dead limbs on others, but the characteristic feature of the disease is a tuft or rosette of small leaves at the end of branches that are otherwise nearly bare of foliage." In this paper the name drouth rosette is applied to the above-described appearance and also to the one in which a cluster of small, lanceolate leaves is found at the base of a twig otherwise bare.

About August 15, 1914, a die-back of the tip of the season's growth was observed in a large number of trees in this orchard.

In these twigs a brown discoloration was evident in the cambial region. This discoloration, in many cases, extended beyond the season's growth, back into the one-year, two-year, and even three-year wood.

There appeared to be several degrees of severity of this injury: (a) The twig and terminal leaves of the season's growth became browned, curled over more or less, and died back, sometimes throughout its whole length but often only partially. Below the dead part the only evident injury was a browning of the cambial region, running down the twig as stated above; (b) the season's growth appeared normal or nearly so, but cambial discoloration was evident for an inch or so back from the tip, and just below the lateral buds; (c) no die-back or cambial discoloration occurred, but there was a premature ripening of the foliage, especially the terminal leaves. These leaves were mottled with pale yellow green and darker green or brown. There was a deep red-brown to purple discoloration along the veins and sometimes over part of the leaf surface, spreading from the tip back over half or more of the leaf, or spreading from the edge of the leaf over part of its surface. From a distance, the foliage of the tree appeared pale yellow-green.*

The appearance of one of these die-back shoots the following summer was that of a completely dead tip from six inches to a foot long, often with a distinct marginal crack between it and the living part below. From some point back of this tip a healthy lateral developed to renew the branch.

Below the dead portion of the twig the bark and cambium were healthy and the discolored zone of the previous fall was found beneath a layer of new xylem. The upper buds on this portion of the branch remained dormant, the lower ones sometimes developed clusters of dwarfed linear lanceolate leaves. The healthy lateral might arise either from above or below the limit of the interior discoloration. Plates VIII and IX show types of these die-back twigs, both with and without the dwarfed lanceolate leaves at the base. Plate XI shows trees from orchard No. 1 exhibiting the die-back and rosette.

* This abnormal appearance of the leaves may be noticed quite early in the season as a mottling of deep green and pale green. Unless, however, conditions are favorable for die-back, it does not develop into the condition of premature ripeness here described.

PATHOLOGICAL HISTOLOGY.

CORK.

Under the microscope the internal brown spots of cork appear as aggregations of cells with brown shrunken contents. A number of the cells, though not all, are shrunken and collapsed. Around the corky portion the healthy cortex cells form a ladder-like arrangement of smaller, more nearly rectangular cells. It is as though they had been stimulated to rapid division in response to the decreased pressure from the direction of the diseased area. (See Plate V, fig. 1.) Outside of this zone the pulp cells are normal in size and form. The close relation of the dead spots to the vascular system is very evident under the microscope.

DROUTH SPOT.

Superficial lesion with smooth surface.—In this type of spot the disease shows merely as a browning beneath the epidermis — an irregular light brown blotch on the skin. On cutting the fruit across it is found that the flesh is normal, the trouble is only “skin deep.” Microscopically, sections of the diseased spots show that the trouble is confined to two or three layers of the hypodermal parenchyma, usually the inner layers, though sometimes the entire hypodermis is affected and a few dead cells are also found in the flesh. The diseased cells retain their normal outline, but their contents have become brown and amorphous. (See Plate V, fig. 2.)

Such a spot may be said to be an early stage of the disease. The injury has occurred very recently and the fruit has made no appreciable growth since. Somewhat later, as the skin of the fruit becomes roughened and cracked, there will be noticed, under the microscope, an abnormal tissue forming beneath the dead cell layers. The cortex cells immediately beneath have become nearly or quite rectangular in outline and are apparently dividing in a plane parallel with the surface of the fruit. This seems to be preliminary to the formation of a cork layer between the dead and the healthy tissue. The outermost layer or two of this new tissue have suberized cell walls, a fact determined by testing with chlor-iodid of zinc and with chlorophyl solution. (See Plate VI, fig. 2.)

Superficial lesions showing wrinkles.—This type of lesion is one entirely similar to the above except that there appears a definite

wavy pattern formed by a series of small wrinkles in the skin. Microscopically, sections through these spots show a series of slight ridges and hollows in the outline of the circumference of the fruit. There is a characteristic arrangement of dead cell areas with regard to these. In a "ridge" the dead cells may not occur, or if they do, they are mostly confined to one or two layers of the hypodermal parenchyma, the dead areas being noticeably thinner than in the "hollow."

In the hollows the browned area is thick, involving often all of the hypodermis and extending like a wedge into the flesh beneath. The apex of this wedge-shaped area is invariably in close proximity to one of the finer vascular bundles. (See Plate VII, fig. 1.)

Small pits, noted especially on the variety Bellflower.—Sections through these pits show the hypodermal parenchyma browned throughout, a brown discoloration in the epidermal cells (the pit is reddish when viewed externally), and a wedge-shaped area in which some of the cortex cells are brown and collapsed. Around this wedge-shaped area the healthy pulp cells have begun to divide in the manner described above under "Cork." There is often a "collection" of vascular branches near the apex of this wedge of diseased cells. This, it will be seen, is very similar to the lesion of fruit-pit or stippen. It should be remembered, however, that these spots were observed in June when the fruits were very small. Fruit-pit does not occur until the fruit is in a late stage of development.

Raised lesions or pimples, noted especially on Fameuse apples.—Sections through these lesions show dead cell layers in the hypodermal parenchyma, and, beneath, a large amount of the tissue which is preliminary to cork formation. The occurrence of this tissue is apparently responsible for the raising of the lesion. The outermost layer or two of this tissue, next to the dead cell layers, give the reaction for suberized cell walls. In many sections the relation of these pimples to the vascular branches in the cortex was very apparent.

Deep-seated lesions.—In this type of the injury the dead cells occur in the flesh of the fruit near the periphery and wedge-shaped areas may be observed extending in toward the vascular bundles. Plate VII, fig. 2, shows a cross section of one of these deep-seated spots in which the tissue affected is that which is transitional between

the hypodermal parenchyma and the cortex. Strips of dead tissue are seen extending toward the vascular endings.

DIE-BACK.

Cross and longitudinal sections of die-back twigs made the second season so that the discolored zone is buried by a layer of new xylem, show, when placed under the microscope, that this zone consists of a tissue called by Sorauer (23) "Parenchymholz." This "Parenchymholz" or parenchyma wood is a tissue in which no normal wood fibers and vessels are recognizable. It consists of irregular but nearly isodiametric cells, with comparatively thin pitted walls and large lumina. The cells themselves appear healthy and contain large quantities of starch. The brown color of the parenchyma zone is due to a brown intercellular substance, the nature of which is not known. It has been suggested by the writer (18) that it may consist of the brown amorphous remnants of dead cells lying pressed between the healthy cells of parenchyma wood, but it may result from the degeneration of the primary wall of parenchyma-wood cells.

The early stages of this parenchyma-wood formation may be observed in sections made of die-back twigs of the current season's growth. Such a twig usually shows entirely dead tissue near its tip and a discoloration in the cambial area running back for a variable distance. Under the microscope this discolored zone shows, if the sections are taken near the tip, a large number of cells with browned contents in the cambium, phloem and pericycle. If sections are made from parts of the twig a short distance below, it will be seen that growth has been made subsequent to the injury. The injured cambium has produced a quantity of the so called parenchyma wood, the browned cells of the phloem and pericycle being pushed outward. Finally, the parenchyma zone becomes buried by a layer of new xylem, outside of which are found normal bark and cambium. (See Plate X, fig. 2.)

SEASONAL HISTORY.

DROUTH SPOT.

The opinion of Mr. J. M. Stevens, who had noticed the disease for five or six years in his orchard at Orwell, Vermont, was, as expressed by him in 1913, that its earliest appearance each year

was about the first of July. As the disease had never been serious in his orchard it is possible that in these years the earliest appearance had been overlooked.

In 1913 diseased fruits were first observed on June 24, at Peru, N. Y. This date was about five weeks after the blossoms had fallen. It is probable that these fruits would have been found somewhat earlier if search had been made. The disease was observed by Mr. Stevens in his orchard at Orwell on June 19.

In 1914 the disease was first observed on June 11, when the young fruits were about one and one-half centimeters in transverse diameter. This was only about twelve days after the blossoms had fallen.

In 1915 the disease appeared on June 11, a little over two weeks after the blossoms had fallen.

In 1916 the date was June 8, about ten days after the blossoms had fallen. The fruits were, on the average, slightly smaller than any in which the disease had been observed in past seasons, many of them being only about one centimeter in transverse diameter.

The later seasonal history seems to be largely influenced by weather conditions. The apples affected early soon drop, but if the season continues dry, as in 1914, fresh spots continue to appear on the larger fruits, having been observed as late as the middle of August. The fruits affected later remain on the tree and become cracked and deformed. If wet weather succeeds the first appearance of the disease, as in 1915, the symptoms tend to disappear, and newly formed spots are not in evidence much later than the beginning of the rainy period. If the early part of the season is rainy, as in 1916, the disease does not occur to any considerable extent, and quickly disappears.

CORK.

Cork appears slightly later than the drouth spot, June 19 being the date it was first observed in 1914 and 1915. In 1916 it seemed to be later than usual, not being found until June 30. When first observed there are usually not so many internal spots in any one fruit as later appear. The spots increase in number during the two or three weeks following. According to the writer's observation all apples which show cork when mature can be recognized as "corky" when half grown. Whether the disease can progress or

originate in storage, as true fruit-pit is said to do, cannot be stated. The writer has never been in the locality at a proper time to observe this.

ORCHARD OBSERVATIONS.

In reporting observations on these diseases made during the seasons of 1913 to 1916, the various orchards in question will, for convenience, be distinguished by number; but in anticipation of the desire of some later worker to identify them, the following list, including owner's name and locality, is given.

Orchard No. 1, owned by the Northern Orchard Co., Peru, N. Y., J. M. Stevens, Manager.

Orchard No. 2, owned by Peter McGee, Peru, N. Y.

Orchard No. 3, owned by the Champlain Valley Orchard Co., Peru, N. Y.

Orchard No. 4, owned by Victor Weaver, Morrisonville, N. Y.

Orchard No. 5, owned by S. H. Clark and Son, Peru, N. Y.

Orchard No. 6, owned by H. T. Kellogg, Valcour, N. Y.

Orchard No. 7, owned by H. L. Scribner, Plattsburg, N. Y.

Orchard No. 7a, owned by H. L. Scribner, Plattsburg, N. Y.

Orchard No. 8, owned by H. E. Heyworth, Peru, N. Y.

Orchard No. 9, owned by Peter Crilley, Peru, N. Y.

Orchard No. 10, owned by J. W. Harkness, Harkness, N. Y.

Orchard No. 11, owned by G. A. Mason, Peru, N. Y.

DRÖUTH SPOT.

Orchard No. 1.—This is an orchard of 4000 trees, 3600 of which are of the McIntosh variety. The soil is described in the soil survey of Clinton County (17) as the Dover fine sandy loam, and characterized as a mellow, rather fertile soil, bearing limestone fragments; one of the best types of soil for general farming in the County. The subsoil is, except for some variation in color, identical with the surface soil. Borings made in this orchard to the depth of six feet indicate nothing in the nature of a hard pan, nor any marked change in soil character. This type of soil is, in general, naturally well drained. The trees were seven years old in 1914, when the first serious outbreak of the disease occurred, and were exceptionally well grown and vigorous, with heavy foliage. The method of culture followed in this orchard from the time of planting

up to and including 1914 was to keep a space cultivated next to the tree rows, and to crop the rest of the ground by a three-year rotation of potatoes, oats and clover.

In 1913 the disease appeared on McIntosh fruits in a few trees in the northeast corner of the orchard. This part of the orchard was in oats. While at first appearing on only a few fruits the amount of disease gradually increased until it affected nearly all of the apples on each tree. The loss in this season, however, was very slight. The only other observation of the disease in 1913 was of a few affected apples on one tree in orchard No. 7. This tree stood in cultivated ground.

In 1914 the disease appeared on a few trees in the part of the orchard where it was found the previous year, and was at first confined to that part of the orchard. This section of the orchard was in clover in the early part of 1914, being plowed in July.

The disease was first observed on June 11; on June 18 it was found to have increased in the area where it was originally found and was also noticed in other sections of the orchard. The earlier affected fruits were dropping. This drop continued later, and is characteristic of the disease on fruits affected when very small.

On June 24 the disease was observed to be more or less prevalent throughout the orchard on scattering trees, often one tree being affected while the next neighboring tree remained free from the disease. This is characteristic of the trouble. The disease on this date appeared to be nearly as prevalent in the cultivated parts of the orchard as in the sod parts. When first observed the disease was confined to a few apples on each tree, but by this time nearly every apple on each affected tree had become diseased. An estimate of the probable loss on this date was 25 per ct. of the crop of the orchard.

On July 3 the disease was observed to be still increasing. It now appeared on larger apples, most of the fruits affected earlier having dropped. It was not, however, apparent that the number of trees bearing diseased fruit had increased. The disease could not be said to be "spreading" as a parasitic disease is understood to do.

On July 20 the disease was observed to be still increasing, early stages (superficial type of lesion) being found on fruits 4 to 5 centimeters in diameter. These early stages continued to be in

evidence as late as August 10. Apples affected as late in the season as this did not drop as the fruits affected earlier did, but hung to the tree and became cracked and deformed.

While the disease occurred to some extent in practically every part of the orchard in this season, four separate areas could be distinguished in which it was much more prevalent than elsewhere. These will be called sections 1, 2, 3 and 4. Section 1, where the disease was first observed, was, as stated above, in clover in 1914; section 2 was in oats; section 3, which was the most badly diseased part of the orchard, and in which a large amount of the summer die-back occurred in 1914, was in a neglected condition. It was intended to cultivate this part of the orchard, but the soil became so hard and dry that plowing was considered impossible. It was, therefore, left untouched throughout the season. Section 4, in which the disease occurred to a less extent than in the other three, was planted to potatoes, and benefited by their cultivation.

In 1915 the disease was first observed in this orchard on June 11. At this date affected fruits were found in about twenty trees, in the parts of the orchard where it had been most prevalent the preceding year, and only in trees which showed the rosette and die-back injuries.

By June 22 the disease had increased. It was now found to occur on trees whose foliage was nearly normal. However, it was possible to find a little die-back in every affected tree.

In this and in other orchards in 1915, the spots on the smaller fruits were more deeply sunken than in other seasons, and showed internally brown, corky areas and cavities extending in to the main vascular branches. In other words, the disease at this time appeared more suggestive of the "confluent bitter pit" or "crinkle" described by McAlpine than at any other period while the disease was under observation. Plate II, fig. 2 and Plate III, fig. 1 are photographs of diseased fruits from this orchard made in June, 1915.

On larger fruits the lesions became more nearly the superficial type of lesion described above. There was, however, comparatively little of this type in 1915, since the disease did not develop fresh stages later than July 1, when the spring drouth was broken. The rest of the season was very rainy and drouth spot was not in evidence.

Beginning with 1915 a new plan of culture was adopted in this orchard, viz., to grow a crop of potatoes one year and to practise

clean cultivation followed by a cover crop the succeeding year. One-half of the orchard was to be planted to potatoes and the other half cultivated each year. Of the diseased areas mentioned above, sections 1 and 2 were in the part of the orchard which was planted to potatoes in 1915; sections 3 and 4 in the cultivated part. There was less disease in sections 3 and 4 than in sections 1 and 2, but the crop was extremely light in the former areas, so that this fact is not especially significant.

In 1916 the disease was first found in this orchard on June 8, showing then as a superficial spot. It was at first found on a single tree, standing in section 1, where the disease had always been prevalent. This tree and the neighboring trees had suffered severely from rosette and die-back. There was, however, nothing to distinguish it from the surrounding trees. A large proportion of its fruit was affected while none of the nearby trees bore diseased fruit. Further search resulted in finding two more trees in this section of the orchard, but somewhat removed from each other, bearing a large number of fruits showing the drouth spot. No diseased fruits were found on the surrounding trees. Search was made in the other parts of the orchard, especially where it had appeared in 1915, but the drouth spot was not found.

This section of the orchard had not been carefully cultivated up to this date, but the spring had been very rainy, and it hardly seemed possible that the trees could be suffering from lack of moisture.

On June 9 eight trees were found showing the drouth spot and on June 10 the number was increased to twelve. All of these trees showed die-back and all stood in the "sick" part of the orchard. Some of these trees bore a large number of diseased fruits; on some only a few fruits were affected. Many trees showing die-back bore good crops of healthy fruits. This had never been observed in previous seasons.

On June 15, 1916, one week after the disease first appeared, careful search resulted in finding it evident to some extent in all parts of the orchard. In all, about thirty trees were found showing the drouth spot. The amount varied from a few apples on a tree to about two-thirds of the crop. All of these trees, without exception, showed die-back injury dating from the summer of 1914. More of these trees were in section 1 of the orchard than in any

other. There seemed some indication in favor of the cover-crop treatment, as in parts of the orchard which bore cover crops only one tree was found showing the disease. This was in a section where the cover-crop was spotted, and may have been in a light spot.

On June 20 the situation in this orchard did not seem greatly changed, but it appeared that the disease was not increasing so fast as it had been. Most of the diseased fruits appeared to have been affected for several days, had stopped rapid growth, were slightly shrunk in the region of the lesions, and in a few cases showed dead tissue extending into the flesh. Such fruits, when cut across, showed dead brown areas and, occasionally, cavities running into the flesh toward some of the main vascular branches, as was observed in 1915. A number of fruits were found on which the spots appeared recent, but the disease had apparently increased much less during the period from June 15 to 20 than it did from June 8 to 15. On the latter date search was made in section 3 of the orchard where the vetch-and-buckwheat cover-crop was turned under in the spring and the disease was found on one tree in the extreme edge of the plat. This section was badly diseased in 1914. The soil at that time was in poor physical condition. It had become too hard to cultivate and was left untou hed. (In 1915 this section was carefully cultivated and sowed with a vetch-and-buckwheat cover crop.)

On June 27 the distribution of the disease in this orchard was much the same as on June 20. It had not appeared on any trees that were not affected on the earlier date. It still appeared only on trees showing the die-back or die-back and rosette injuries. It was still possible to find a number of fruits showing early stages of the disease, some, even, with exudate, but the disease was not increasing to any appreciable extent. The spots were still superficial in the early stage, showing corrugation very markedly. Old spots usually showed internal brown corky areas, as mentioned above; but no severe sunken lesions, such as occurred in 1915, could be found. A number of the earlier affected fruits had dropped. Some still persisted and were beginning to show surface roughness and cracks.

On July 12 the increase of the disease was apparently past, there being practically no fresh stages. In fact, the loss in this

season nearly all occurred during the first two weeks after the appearance of the disease.

Orchard No. 2.—This is a small orchard of mixed varieties, principally Fameuse, McIntosh and Northern Spy, on the farm adjoining that of orchard No. 1. The soil on the two farms is the same. The orchard was carefully cultivated during the early part of 1914, and sowed to buckwheat early in July. The trees were about twenty years old in 1914.

The disease was observed on July 3 on Northern Spy apples, and a few days later on McIntosh. Several Northern Spy trees bore affected fruit, but only two McIntosh. Many of the Northern Spy trees were suffering from winter-killing of the roots, which had occurred the preceding winter. None of the McIntosh were so affected. Affected fruits could, no doubt, have been observed at an earlier date had a visit to the orchard been made. The progress of the disease in this season was identical with that described for orchard No. 1.

In 1915 the disease was found in this orchard on June 16, in a few Fameuse trees. These trees were suffering from rosette and die-back. The Fameuse fruits affected showed both the external drouth spots and the internal spots of cork. Many of them showed genuine cork, with no external abnormality.

On June 22 more Fameuse trees were found showing the drouth spot and cork. The McIntosh trees which bore diseased fruit in 1914 and which were also affected with die-back, showed the drouth spot. The Northern Spy trees which showed the drouth spot in 1914 were badly affected with die-back but did not bear fruit in 1915.

As in orchard No. 1, the drouth spot did not develop later than about July 1. Most serious in this orchard in 1915 was cork, appearing alone and also in association with the drouth spot. The orchard was in clover in 1915 and the crop cut for hay.

In 1916 a crop of clover hay was again raised in this orchard. All of the trees bore, including the Northern Spys. Neither drouth spot nor cork appeared during the season. The crop was healthy.

It should be stated that during these three years both the drouth spot and cork appeared in a certain restricted area in this orchard. This area is slightly higher than other parts of the orchard, and, according to the owner's statement, its soil is drier.

Orchard No. 3.—This is a small orchard of two varieties, Fameuse and McIntosh, the Fameuse being about twenty years old, the McIntosh about ten. It occupies one side and the bottom of a small creek gully, sloping to the southeast. One corner of the orchard occupies the highest part of the ridge of the slope. In 1914 this area was sowed to oats and the part lying lower was carefully cultivated. The soil is described in the Clinton County survey as the Dover gravelly fine sandy loam, not greatly different from the Dover fine sandy loam. It is a soil found occupying small ridges and slopes through the uplands. It is stated that on account of the loose, porous nature of the subsoil, crops sometimes suffer from lack of moisture during periods of dry weather. This statement is not made regarding the Dover fine sandy loam.

The disease was first noticed in this orchard on July 8, 1914, but was probably evident before that date. Every Fameuse tree in the higher part of the orchard bore diseased fruit and nearly every fruit on affected trees became diseased. None of the Fameuse nor McIntosh in the lower lying part of the orchard showed the disease. (There are no McIntosh trees in the higher part.) The diseased Fameuse fruits showed both the external and internal lesions characteristic of drouth spot and also the internal lesions characteristic of cork.

In 1915 the whole of this orchard was kept under careful cultivation. The disease was observed here on approximately the same date as in orchard No. 1. A description of its occurrence in 1915 would be repetition of the statement just made regarding conditions in 1914.

There was no drouth spot in this orchard in 1916, but some cork occurred as mentioned later.

Orchard No. 4.—This is a mixed orchard of McIntosh, Northern Spy and Fameuse. The trees were about fifteen years old in 1914, and were well grown, with heavy green foliage. The soil is the Dover fine sandy loam. Careful cultivation is practised in this orchard every year.

In 1914 the disease was first observed on June 22. On this date numerous diseased fruits were found on one McIntosh tree in a corner of the orchard. By July 7 the disease involved about two-thirds of the crop of this tree, most of the affected apples being found on the lower limbs. A few diseased fruits were found on the next

tree, also a McIntosh. The disease was not found on other McIntosh trees nor on Fameuse, but occurred on two Northern Spy trees in the row next to the one containing the affected McIntosh trees.

In 1915 the disease was observed in this orchard on June 19. It occurred on the two McIntosh trees which bore affected fruit in 1914 and also on one McIntosh tree in another part of the orchard. This tree was not diseased in 1914. The Northern Spy trees on which the disease was found in 1914 were affected with die-back of the previous summer's origin, and rosette, but did not bear fruit in 1915.

Search was made for drouth spot in this orchard on June 21, 1916. Two-thirds of the apples on the one McIntosh tree where the disease was first found in 1914 were affected on this date. The disease was not found on either of the other two McIntosh trees which had borne diseased fruit in the past. It is to be noted that the McIntosh tree in question is the one which has each year been most seriously affected, both with drouth spot and with die-back and rosette. The set of fruit on this tree was poor as compared with other McIntosh trees in the same orchard, although it had blossomed fully as well. One of the Northern Spy trees, showing more die-back than the other, bore a very few diseased fruits.

Contrary to the usual practise this orchard was not cultivated in 1916 but was left to grow up to quack grass and weeds.

Orchard No. 5.—This is a large orchard of several varieties: McIntosh, Fameuse, Northern Spy, Ben Davis, Baldwin. The soil is described in the Clinton County survey as the Coloma fine sandy loam, a soil differing from the Dover fine sandy loam chiefly in the absence of limestone fragments and in a generally lower agricultural value. The crops on this farm are, nevertheless, usually good. The orchard is well cultivated each year and a cover crop sowed in July. The trees are about twenty years old.

The disease was observed in this orchard on July 6, 1914. A large number of McIntosh and a few Fameuse and Ben Davis trees were found bearing affected fruits. Later, the disease was found very prevalent on Northern Spy. The diseased Fameuse fruits, as in other cases, showed both drouth spot and cork lesions, and there were, in addition, several Fameuse trees which bore full crops of fruit affected with genuine cork, no external spots being evident. The disease was largely confined to one section of the orchard,

but no difference in soil or treatment between this and other sections could be observed.

In 1915 drouth spot was found in two or three McIntosh trees in this orchard on June 18. These trees also showed the die-back and rosette injuries. Many of the McIntosh trees which were affected the previous year did not bear. The Northern Spy trees which bore diseased fruit in 1914 were observed to be affected with die-back. They did not bear in 1915. There was some drouth spot on Ben Davis, and also a little cork on Fameuse, but as the Fameuse crop was very light, most of the trees not bearing, these observations are of no particular value.

There was very little drouth spot and no cork in this orchard in 1916. One Ben Davis tree in the affected section of the orchard showed a type of the disease which seemed transitional between drouth spot and cork. A number of nearby Ben Davis trees which had been badly diseased with drouth spot in the past two years, and which showed the foliage abnormalities, bore large crops of healthy fruit in 1916.

One fact without satisfactory explanation is the occurrence in 1916 of typical drouth spot in three Baldwin trees in this orchard. These trees had never, to the writer's knowledge, exhibited the disease. They did not bear in 1915 and were either healthy or escaped the writer's attention in 1914. That the latter may be the explanation is probable, since they were badly affected with die-back. These trees stood in a remote corner of the orchard.

The Northern Spy trees which were badly diseased in 1914, and in which the die-back occurring that year was still evident, bore a large crop in 1916, but no fruit affected with drouth spot could be found.

Orchard No. 6.—This is a mixed orchard of old trees, 60 to 75 years old, Fameuse being the variety most represented. The soil is described in the Clinton County survey as the Dover loam, a soil recognized as the strongest in the county. The land slopes to the east toward Lake Champlain, has good surface drainage, but is not underdrained, though apparently needing such treatment. It is usually wet late in the spring. In 1914 the orchard was plowed early and left for some time before harrowing. It was later harrowed at considerable intervals and in such a way that the soil was in bad, lumpy condition between harrowings. This bad condition was

evident at the time of the first observation of drouth spot and cork in this orchard.

The disease was first observed on June 24. Varieties affected were Fameuse, Bellflower and Oldenburg. On July 8 it was estimated that 75 per ct. of the Fameuse fruits in this orchard were diseased. As in the case of the Fameuse in orchard No. 3, all of these diseased fruits showed the internal spots characteristic of cork, often with no accompanying external lesions though many of them also showed the external drouth spots. There was practically an entire crop loss from these Fameuse trees when picking time arrived.

In 1915 specimens of drouth spot were found on one Fameuse and one Oldenburg tree on June 16. Some of the other Fameuse trees showed a little die-back and rosette, but their fruit was normal at this date. Subsequently, cork developed in these Fameuse, involving practically the whole crop of the orchard. The orchard was cultivated early and sowed to oats.

In 1916 neither drouth spot nor cork occurred. This is remarkable in view of the widespread occurrence of cork in the previous years. The orchard was in clover in 1916, which, in connection with the rainy season, undoubtedly caused better soil moisture conditions than in 1914, when the soil was in hard, lumpy condition, or in 1915 when a crop of oats competed with the trees during a very dry spring.

Orchard No. 7.—This is a large orchard of McIntosh, Wealthy, Northern Spy, Fameuse and other varieties. The trees are about twenty-five years old and in good condition. The soil is the Dover fine sandy loam. Cultivation is practised next to the trees, a strip of sod being left in the center of the row. The drouth spot appeared in one McIntosh tree in 1913, and took the whole crop of several McIntosh trees in 1914. In 1915, on June 28, one tree which bore affected fruit the previous year was found showing the disease. This tree and several others which bore diseased fruit the previous year showed the die-back and rosette injuries (of the previous summer's occurrence). No additional cases of the disease in McIntosh fruits were found; nor did any of the Wealthy trees in the orchard show the disease.

In contrast to the above, in an orchard across the highway, orchard No. 7a, a large number of Wealthy and Fameuse trees bore diseased fruit in 1915. The Wealthy trees, in particular, had

an over-load of small fruit and every apple became affected with drouth spot. Several of the Fameuse trees had borne corky fruit the year before. No die-back or rosette was found in these trees. This orchard was cultivated, but very poorly. The soil was in a hard, lumpy condition at the time the disease was first observed, and for some time before. The soil type in the two orchards is the same.

No drouth spot occurred in either orchard, No. 7 or No. 7a, in 1916. Cork, however, was present to some extent, as mentioned later.

Orchard No. 8.—This is a small orchard of McIntosh, about eighteen years old. The soil is, again, the Dover fine sandy loam. The orchard is in sod, and usually bears a heavy crop of hay. The drouth spot had never appeared here until 1915, when it took a large portion of the crop. There was no die-back or rosette injury. There was no disease in this orchard in 1916.

Orchard No. 9.—This is an old orchard of several varieties including a row of half a dozen McIntosh and three Fameuse along one side next to the highway. The trees are about twenty years old. The soil is the Dover loam. The orchard is in sod and generally neglected as to pruning and spraying. The soil moisture conditions in this orchard do not appear good. Even in a season of abundant rain the soil becomes dry and hard. Borings in this soil to a depth of four feet did not reveal a hard pan.

The drouth spot took nearly the whole crop of the McIntosh trees in 1914, and in 1915 was equally severe, except that some fruits escaped, due to the general failure of the disease to develop after July 1. Die-back and rosette developed in these trees following the summer of 1914. In the spring of 1916 they were in worse condition from these foliage abnormalities than any other trees found. One or two appeared in almost a dying condition. Die-back and rosette were also very severe in the Fameuse trees. This was extraordinary, since few Fameuse trees in other orchards have been observed showing them, and then only to a very slight extent.

In 1916 this orchard was one of the few in which drouth spot occurred. It was found in four of the diseased McIntosh trees. It did not, however, involve the whole crop of these trees. In no case was more than one-half of the fruit affected. The crop on these trees was light. One McIntosh tree, which seemed in a better

condition than the others, showing less of the die-back and rosette, bore a large crop of healthy fruit. Cork occurred in the Fameuse trees, as mentioned later.

Other orchards.—In addition to the orchards described above, drouth spot has been found in several others at different times. Some of these cases will be mentioned briefly.

In 1915, in particular, the disease was observed in several orchards in which it had not appeared in either of the two preceding years. The case of orchard No. 8 has been discussed above. Notable was the occurrence, this year, of the drouth spot in three trees in an orchard where the soil was rich, mellow, and in the best possible tilth. In no instance where the disease occurred in 1915 for the first time was there any of the die-back or rosette.

In the years 1914 and 1915 the drouth spot was found occurring in an orchard at Gordon's Landing, Vermont. The soil here is heavier than in Clinton County, N. Y., and shallow, being underlaid by limestone which comes to the surface in many places. This orchard was not visited in 1916.

In the same seasons drouth spot occurred in a few McIntosh trees in a young orchard near Crown Point, N. Y. These trees stood in very shallow soil, with rock close to the surface and outcropping nearby. In 1916 there were a very few diseased fruits on these trees, the great part of their crop being healthy. In this season drouth spot was also found on another McIntosh tree which stood on a ridge of land in this orchard. This tree and other nearby trees appeared in a very much weakened condition, the cause of which was not ascertained.

An orchard in which the disease has been severe is that owned by Mr. J. M. Stevens at Orwell, Vermont. The writer did not visit this orchard except in 1916. The observations here reported were made by Mr. Stevens, but as he is manager of orchard No. 1, and has watched the disease closely in both orchards, they should be accepted as reliable.

There was a considerable amount of the drouth spot in this orchard in 1914. It seemed to be confined to the drier parts of the orchard. Die-back occurred on a few trees.

In 1915, under comparatively clean culture, the disease was quite prevalent in the "shaly" parts of the orchard. The soil here is a clay loam in which shale fragments are abundant. It is underlaid

by shale, and in many places is shallow. In a small block of trees where the soil is the same, but where a crop of sweet clover was grown, cut and left as a mulch, the disease did not develop. The clean-cultivated parts of the orchard were seeded to alfalfa in August. In 1916 very little disease developed. It occurred to a very slight extent on six trees.

Part of this orchard stands on a deeper soil of heavy clay loam, not carrying shale fragments. Only three trees in this part have shown the disease. They were badly diseased in 1914. They then stood in poorly drained places where, during the spring drouth, the soil was lumpy and hard. These places were tiled, and in 1915 there was much less disease on the trees. In 1916 a few diseased fruits were found on one of them.

CORK.

True cork as distinguished from drouth spot was quite prevalent in Clinton County in 1914. Its occurrence where the internal lesions were associated with the external drouth spots has been mentioned above. The following observations are on the disease as it usually appears; viz., as an internal spotting with the outer surface of the fruit smooth in the early stage, but later becoming lumpy and knotty due to uneven growth of the tissues.

The disease was first observed on June 24, in orchard No. 6, as mentioned above. At this time the fruits were from about one and a half to two centimeters in diameter.*

In most of the orchards studied the disease appeared on trees which could in no way be distinguished as to growth, vigor, or favorable location from neighboring trees that were free from the disease. Usually, the entire crop of a particular tree was corky. Sometimes the entire crop of certain branches was affected, the apples on other branches of the tree remaining normal. The owners of the various orchards under observation stated that certain trees, and even certain branches of some trees, were particularly susceptible to cork; also, that these trees always bore corky fruit if any in the orchard did.

Nothing very definite as to the moisture relations in most of these orchards could be learned. In several well cultivated orchards

* McAlpine (13) states that the earliest stage of the disease observed by him in New South Wales was on November 30, when the fruits were "about the size of a walnut."

there were very few trees bearing corky apples, and in a few there were none. One sod orchard, No. 10, was remarkable. It is a small orchard containing about twenty Fameuse trees twenty years of age, and a few trees of other varieties. The soil is the Coloma fine sandy loam. At the time of observation, in August, it was very dry and hard. A heavy crop of hay had been grown in this orchard. The Fameuse trees bore heavily in 1914. Their entire crop was corky, deformed and small, and the trees did not make much growth.

One other orchard deserves special consideration. This is orchard No. 11, a small orchard, mostly of the Fameuse variety. The soil is the Dover fine sandy loam. The orchard was in sod, bearing a light crop of grass. The trees, about twenty years old, were vigorous, and made a good growth in 1914, with heavy, dark green foliage. An exception was found in a row of trees along one side of the orchard and next to a row of elms. These trees were less well grown and smaller than the other trees in the orchard. They made less growth in 1914, their foliage was paler and yellowish. All of their fruit was corky, while other trees in the orchard bore healthy fruit.

Cork was somewhat less prevalent in 1915 than in 1914. It occurred along with the drouth spot in orchard No. 2 and orchard No. 3, in the same trees that were diseased the year before. The trees in Orchard No. 6 which bore fruit showing both drouth spot and cork in 1914 were badly affected with cork in 1915. In various other orchards certain trees and individual limbs of trees which bore corky fruit in 1914, did so also in 1915. The Fameuse trees in orchards Nos. 5, 10 and 11 which had been diseased in 1914 did not, in most cases, bear in 1915. The few trees that did bear, bore corky fruit. The Fameuse crop of 1915 was very light throughout the locality.

Cork was very scarce in 1916. It was found in two trees in orchard No. 9. These trees, as elsewhere noted, were badly affected with rosette and die-back. Cork also occurred in four trees in orchard No. 3. These trees were some of those which had borne "corky" fruit in the preceding two years. The Fameuse trees in this part of orchard No. 3 have the reputation of having never borne healthy fruit. Some of them did so, however, in 1916. Cork was also found in five trees in orchard No. 7a, these being trees

previously diseased. With these exceptions, cork was absent this year from the orchards under observation, even from trees which had been looked upon as "corky" trees, that is, which could be relied upon to produce specimens of the disease every season. Particularly striking was the complete absence of cork from orchard No. 10, though this orchard was again in hay; from orchard No. 6; and from the row of trees in orchard No. 11, in which it had occurred in 1914.

DIE-BACK AND ROSETTE.

The first manifestation of these foliage abnormalities in 1914 was the appearance of bare tips due to the failure of the buds to start in the spring. This was first seen in orchard No. 1. Later in the season many of these tips died back and developed the peculiar condition described above (page 483) as rosette. On July 13 the writer visited a number of orchards near Peru in company with Dr. Charles Brooks of the Bureau of Plant Industry. At this time Dr. Brooks pointed out the occurrence of this peculiar condition in orchard No. 1 and its apparent association with the drouth spot, and mentioned its similarity to the trouble known as rosette occurring in the apple-growing regions of the Pacific Northwest.

Subsequently, die-back and rosette were observed in various orchards; viz., in orchard No. 2, on the Northern Spy variety; in orchard No. 7, on McIntosh; and in orchard No. 9, on McIntosh. In all these cases it occurred on trees which bore diseased fruits. It was reported, also, on such trees in the orchard of J. M. Stevens at Orwell, Vt.

These foliage abnormalities were most prevalent in orchard No. 1, in that section where the diseased fruits had been found the preceding year, and where they were especially abundant in 1914. There was further apparent association of these abnormalities with the disease on the fruit. Every tree in this orchard which was affected with them bore diseased fruit, if it bore at all. Some did not bear. Some trees were found with diseased fruit, but with normal foliage.

The die-back and rosette, while occurring, did not appear serious in extent in orchard No. 1 in 1914. It must be stated, however, that a large amount of pruning was done by the manager throughout the summer, when the diseased foliage was removed.

As early as July 21 the premature ripening of the leaves described on page 484 had become evident, and was more noticeable by the middle of August. This was nearly universal throughout the portions of the orchard in which the diseased apples had appeared, occurring in trees which bore diseased fruit and in trees which showed the die-back and rosette.

About August 15 the die-back of the current season's growth was first noticed. It occurred in a large number of trees in the drouth spot sections of the orchard. It was quite prevalent and continued to appear as late as September 15, when the writer left the locality. The manager of the orchard reported that it continued even later, and expressed the opinion that it was responsible for the widespread occurrence of the die-back evident in the spring of 1915.

In 1915, die-back, resulting from the death of the season's growth the summer before, was prevalent in several orchards. The same trees usually showed some of the rosette, though this was less conspicuous. These abnormalities were most serious in orchard No. 1 where the drouth spot was also most evident; but they occurred in other orchards in trees which bore diseased fruit the previous year, and where the die-back of the season of 1914 occurred. All of these trees that bore in 1915 bore diseased fruit. Some of them, particularly the Northern Spy variety, did not bear.

The following are some of the orchards in which drouth spot and summer die-back occurred in 1914 and the die-back was prominent in the spring of 1915: Orchard No. 1, on McIntosh, about twenty trees seriously affected, and a large number of others less so; orchard No. 2, on Northern Spy and Fameuse; orchard No. 4, on McIntosh and Northern Spy; orchard No. 5, on McIntosh and Northern Spy; orchard No. 6, on Fameuse; orchard No. 7, on McIntosh; and orchard No. 9, on McIntosh.

Fresh die-back of the current season's growth was observed in orchard No. 1 about August 15. It was much less in extent than that occurring in 1914; in fact, was found only in a few trees.

Somewhat more common than this die-back, though much less prevalent than in the preceding season, was the premature ripening of the foliage described on page 484 under c. In connection with this a significant appearance was evident about September first. The season of 1915 was abnormal, May and June being excessively dry, while July and August were rainy. In consequence, many

trees stopped growth early and later put out new growth, amounting to a foot or more on some branches. Several branches showed the typical premature ripening in their lower portions. This stopped abruptly and was succeeded above by a foot or so of new and normal growth, as though the incipient injury had been arrested by the resumption of growth. On the same trees were found twigs that had not started to grow a second time but presented the prematurely ripe appearance of terminal leaves which is believed to be the first stage of die-back.

The above would indicate that the die-back occurs during a period of drouth and may be arrested by a succeeding moist period. This would explain the greater amount of die-back in 1914, since that season was not only dry in May and June but the drouth continued throughout the summer.

In the record of orchard observations some emphasis has been placed upon soil type. This has been done to bring out the fact that these diseases occur on the best types of soil in Clinton county and are not connected with any marked condition of infertility of the soil. While they are found chiefly on one soil type, the Dover fine sandy loam, there is no ground for suspecting a wrong condition peculiar to this soil. There is a greater number of productive orchards on this type of soil than on any other. In certain instances the presence of the drouth spot seemed connected with a condition of shallow soil, but borings in two of the worst affected orchards revealed a deep soil with nothing in the nature of a hardpan, unless at a considerable depth. It is apparent that these diseases may occur in the best soils of the county under thorough cultivation, and in young vigorous trees, as readily as under less favorable conditions.

ECOLOGY.

FRUIT-PIT OR STIPPEN.

Sorauer (23) states that in Germany stippen occurs commonly on loose soil and in dry years. It affects mostly soft-fleshed, early varieties. Firm-fleshed sorts suffer little. In England, the disease is said to occur with alternation of sun and shower, or even of heat and drouth. The season of 1911 was hot and dry, followed by sudden rains. Stippen was abundant. In 1912 the season was rainy throughout, and there was very little stippen (McAlpine [13]).

McAlpine (13) states that in Australia the prevailing opinion is that this disease occurs mostly in wet summers. A few growers have experienced it in dry seasons. It is believed that when rainfall is equally distributed and the rains not followed by a period of drouth stippen is not so serious. A light crop with abnormally large fruit is more liable to stippen than a heavy crop of average sized fruit equally distributed over the tree. Young and vigorous trees making rapid growth may have pitted fruit from rapid transpiration and excessive growth interfering with the regular development of the vascular network.

Brooks and Fisher (3), conducting irrigation experiments with fruit-pit, found that heavily watered trees, especially trees heavily watered late in the season, had a greater percentage of diseased fruit than trees receiving medium or light watering.

DROUTH SPOT, CORK AND DIE-BACK.

The writer's observations show that these diseases may occur in both wet and dry seasons. There is, however, a marked relation of weather conditions to the disease. They tend to disappear during wet weather and are much more serious during a dry period, especially dry weather occurring early in the season. The following statements will serve to make this clear. The spring of 1914 was very dry and there was a great deal of high wind. The drouth continued through the summer. There was an abundance of drouth spot, of cork and of die-back of the current season's growth. It was dry and very windy early in the season of 1915, but July and August were rainy. Under these conditions drouth spot was abundant early, on the smaller fruits, and in a severe form. It even occurred on trees which had not suffered in previous years. It failed to develop on the larger fruits during July and August. Cork was quite prevalent in this season, the injury appearing before the dry period was over. Die-back of the current season's growth was inconsiderable, occurring only in a few branches of certain badly affected trees. There was considerable evidence of recovery from preliminary stages of die-back, the twigs making a large amount of vigorous growth beyond the unhealthy part.

The spring of 1916 was rainy. Drouth spot and cork were not entirely absent, but were greatly reduced, appearing only in trees which in past years had been very badly diseased. Drouth spot

appeared early, in a milder form than in 1915, and had stopped development by the end of June. Cork was slightly later in appearance than usual, and occurred in inconsiderable amounts. Summer die-back did not appear.

The following table gives the record of rainfall during the seasons under discussion. The records were taken by Mr. J. W. Harkness, cooperative observer of the U. S. Weather Bureau, at Harkness, N. Y., four miles from Peru, and probably represent with fair accuracy the rainfall during those seasons for the apple-growing sections of the lower Champlain valley.

TABLE I.—RECORD OF RAINFALL AT HARKNESS, N. Y., DURING THE YEARS 1913-16.

Year	May	June	July	August
	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>
1913.....	2.09	1.45	3.78	1.15
1914.....	.44	2.64	1.75	2.93
1915.....	1.14	1.93	4.48	4.17
1916.....	3.25	3.68	.....	.....
Average 10 years — 1903-1912.....	2.41	3.29	3.66	2.22

CAUSE OF THE DISEASE.

GENERAL DISCUSSION.

It is evident that we have under consideration, not two distinct apple diseases, but, at the most, two types of the same disease: (a) Drouth spot, with which are associated abnormalities of the foliage, called drouth die-back and drouth rosette; and (b) cork, which may occur in association with drouth spot, but which often occurs independently, and is then not associated, except rarely, with any disease of the foliage. Cork is most common in the Fameuse variety.

Before formulating a theory as to the cause of these diseases certain possible causes need to be eliminated. A discussion of these follows:

PARASITIC ORGANISMS: FUNGI AND BACTERIA.

Certain facts operate against considering a parasitic organism the cause of these diseases. They do not seem to be infectious, that is, to spread from one tree to another after the manner of parasitic

diseases, but rather to affect certain trees in certain locations, and, in the case of cork, even certain branches of one tree, season after season. In the case of drouth spot, the lesion appearing on the surface of the fruit does not increase in size. This was determined by drawing rings around several spots and watching developments as the fruit remained on the tree. Indeed, in both drouth spot and cork the trouble seems to be an injury rather than a disease. After the injury occurs subsequent changes seem to be due to further growth of the fruit and attempts to outgrow the injury. There is no progressive development of the disease. The very apparent association of the lesions in the fruit with the vascular system suggests that the trouble is of non-parasitic origin, and reveals a marked resemblance to fruit-pit or stippen, a trouble with which a number of competent workers have been unable to connect any parasitic organism.

In addition to the above, some first hand evidence was sought. A large number of sections have been made of lesions on the fruit, and of the discolored portions of the die-back twigs, and various staining agents employed; but in no case could any organism be found associated with the injured cells. In the fall of 1914 and in the early summer of 1915 several attempts were made at isolation of an organism from die-back twigs by planting bits of diseased tissue in plates of nutrient and potato agar. A few similar attempts were made with bits of tissue from drouth-spot-injured apples. None were made with cork. All of these attempted isolations were without result.

INJURY BY INSECTS.

Specimens of the drouth spot were submitted to Prof. G. W. Herrick and Prof. C. R. Crosby of the Department of Entomology, New York State College of Agriculture. It was their opinion that the injury was not caused by insects and that it was unlike any known insect injury to apple fruits.

SPRAY INJURY, MECHANICAL INJURY, SUNSCALD.

The evidence is against any of these causes. The drouth spot does not resemble spray injury in any recognized form, but the significant fact is the occurrence of both these diseases in sprayed or unsprayed orchards indifferently. They usually first appear between the dates of the calyx spray and the second codling moth

spray, and in orchard No. 1, where the drouth spot has been most prevalent, no application later than the calyx spray has ever been made. Mechanical injury of the fruit brought about by rubbing against branches in the wind sometimes occurs, but this is quite different from drouth spot. It consists in brown, leathery areas in the skin of the fruit, usually with small scratches or holes, evidences of the rubbing. The position of the fruit in the tree does not allow consideration of the idea of sunscald, for the disease occurs in any part of the tree, inside or out, and on any side of the fruit, whether shaded or sunny.

WINTER INJURY.

The idea that winter injury may be directly responsible for the die-back and rosette injuries of these trees is not tenable, since the initial stages of die-back occur in late summer to growth which has been made that season, and to twigs in which the wood of the previous year is entirely normal. Although the writer (18) has observed that formation of parenchyma wood, such as occurs in these die-back twigs, follows winter injury to the cambium, it seems that here it follows some cambial injury which takes place during the growing season.

There was in this locality, in the winter of 1913-1914, a considerable amount of winter injury to the roots of apple trees. It was thought that winterkilling of the roots might be associated with the die-back and rosette injuries. Examination was made, in May, 1915, of the roots of some of the trees in orchard No. 1. Surface roots, which, in the cultivated parts of the orchard, could easily be reached, showed, in many cases, browned centers and live outer parts, as though they had been injured by cold during the winter of 1913-1914, and had laid down one season's growth outside the injured portion. This condition, however, was found in trees with normal foliage and fruit, as well as in those affected with the drouth spot, die-back, and rosette injuries. Three trees which were very badly affected with die-back and rosette were removed and their root systems examined. A fourth tree, in like condition, was given a severe pruning, but as in 1916 its appearance was not improved, it, too, was dug up and examined. Three of these trees showed, just below the union of stock and cion, a large amount of corky, rough, outer bark while the bark underneath was normal. The fourth tree showed a small growth of what was

apparently crown-gall on an upper root. The root systems of all four trees were healthy; there were not even any of the surface roots with browned centers, as observed in other trees.

It does not appear that winter injury to the roots can be associated, even as a contributory factor, with the occurrence of die-back and rosette. Further, manifestations of root injury, as observed in this locality in 1914 and 1915, are quite different. In severe cases the leaves wither and die before they have attained much size, and usually certain large branches die throughout their length; but there is no condition like die-back or rosette.

An unhealthy condition of the roots is, apparently, not necessary to the presence of the disease. Allen (1) has made a study of the condition of the roots of apple trees in the Hood River valley, noting, among other things, the relation of root condition to the occurrence of "fruit-pit," and "winter injury" or "die-back." (These troubles may be similar to the drouth spot and die-back of the Champlain valley.) He states: "The presence of 'fruit-pit' was found to be worse under the worst conditions of the soil, and upon trees having root systems in the most critical condition. *In less serious conditions of soil the roots of the 'pit trees' were either normal in vigor or nearly so.*

"Winter injury appears to be most prevalent on soils of poor condition, but no relation was found to exist between the seriousness of the trouble and the condition of the roots of the trees; the roots of some trees so affected, however, were found to be in very poor condition."

FRUIT-PIT OR STIPPEN.

Various theories to account for fruit-pit or stippen formation have been advanced by different workers. Only those which assign a so-called physiological cause will be reviewed here. Other causes have been suggested, but there is no evidence in favor of them. Such are parasitic fungi, insects, mechanical injury, spray injury.

Wortmann (25) believes the injury to be due to an increased concentration of the cell sap through water lost by transpiration. Excessive transpiration and poor conduction of water from cell to cell are thought to be the factors most concerned. From a study of several varieties susceptible and not susceptible to stippen, Wortmann finds that, in general, non-susceptible varieties have thicker walled, smaller epidermal cells, and fewer stomata or other openings in the cuticle. He considers this a protection against transpiration.

Zschokke (26) comes to much the same conclusion as Wortmann. He emphasizes the factor of irregular conduction from cell to cell and connects the occurrence of the spots in larger numbers near the calyx end of the fruit with the larger number of stomata and other openings in that region, and with a possible higher rate of transpiration by the upper one-third of the apple.

Sorauer (24) suggests that stippen is caused by too rapid maturation of individual cell groups. In every fruit the tissue is unequally filled with reserve materials. Untimely dryness of the soil may interfere with the amount of organic material necessary to the full development of the fruit. Individual tissue groups will be especially poor in contained material and will mature (ausleben) more quickly.

Evans (9) offers the following theory: Abundant transpiration and copious absorption of the water by the roots occurs, as on a warm, bright day. The transpiration is suddenly checked, without a corresponding check in absorption. The cells of the flesh in proximity to the fibro-vascular bundles become gorged, distended with water, burst and die. Adjacent cells, being dependent on these for their water supply, also die, producing small brown areas in the flesh of the fruit. The conductive tissue is not affected, since it is strong walled and adapted to withstand pressure.

McAlpine (13) disagrees with Evans on the following grounds: (1) The cells of the flesh are closely pressed together and could not burst; (2) if thin slices of the "pitted" portions of the fruit are placed in water the cells regain their original size; (3) it is very easy to rupture the cell walls in the process of preparing sections; (4) the well known water-core disease is generally conceded to be due to a superabundance of water which passes through the cell walls under pressure, fills the intercellular spaces, driving out the air and causing the water-soaked appearance. In a later report he suggests that sometimes bursting of the cells from turgor may cause the disease. (McAlpine [16]).

McAlpine offers the following to explain the occurrence of "bitter pit" in both a wet and a dry season: The supply of water to the cells is deficient during a critical period of growth. In a wet season the apple grows very rapidly. The network of conductive tissue cannot develop rapidly enough to maintain properly balanced proportions. Thus the water supply becomes deficient. In a dry

season transpiration is excessive and the soil, lacking in moisture, cannot supply a sufficient amount to the fruit, resulting in a drying of the cells, particularly those at the surface.

"Confluent bitter pit", or "crinkle" is thus explained by McAlpine: Excessive transpiration caused by sudden heat, combined with rapid growth which produces partial rupture of the epidermis, may result in the vascular network not being formed over large areas. These may develop "confluent bitter pit."

McAlpine attributes the greater amount of stippen at the calyx end of the apple to the greater transpiration which takes place in that region. He assumes this greater transpiration since the number of stomata at that end is about three times the number at the opposite end.

According to McAlpine, interior stippen not related to external lesions (the cork of Clinton county) may be explained in one of two ways: (1) The spots appeared when the apples were very small and were later enclosed by the growth of the flesh; or (2) the injury progressed inward from external spots following the conductive tissue.

DROUTH SPOT AND CORK.

Chandler (5) has shown that under conditions of reduced water supply to the roots, and increased transpiration, the leaves of an apple tree may rob the green fruit of its water, causing it to wilt. This is due to the fact that the cell-sap concentration in the leaves is somewhat higher than in the green fruit. Hence, the direction of the osmotic flow would then be from the fruit to the leaves. It seems probable that, if the cork and drouth spot are due to a combination of reduced water supply and excessive transpiration, they are caused in this manner, rather than by an excessive transpiration of the fruits themselves.

RELATIVE RATE OF TRANSPIRATION OF YOUNG FRUITS AND LEAVES.

The measurement of the rate of transpiration of fruits while attached to the tree cannot be accomplished with any degree of accuracy. McAlpine (14) has measured the amount of water given off by apples enclosed in glass bulbs attached to the tree. His results show an increase in the amount of water transpired as the fruit increases in size. Unfortunately, it cannot be said whether this increase is relative as well as absolute; that is, whether there

is an increase or decrease in the amount of water transpired per unit weight of fruit. There seems to be no good method of determining this. It was thought something might be learned from the measurement of the amount of water given off by detached fruits. For this purpose fruits were removed from the tree and the ends of their stems paraffined. They were weighed immediately, and subsequently at intervals of twenty-four hours. For purposes of comparison detached leaves were similarly treated. The results are given in Tables II and III.

TABLE II.—AMOUNT OF WATER TRANSPIRED FROM YOUNG DETACHED APPLE FRUITS.

Date	Variety	Number of fruits	Transv. diam. of fruits	Average weight of fruits	Water transpired; measured in grams per kilogram of green weight per hour			
					24 hrs.	48 hrs.	72 hrs.	96 hrs.
1916			<i>Mm.</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>
June 13	Fameuse...	25	8-12	0.837	2.33	4.72	4.45	.....
	McIntosh...	25	11-15	1.45	.918	1.35	1.51	.....
June 17	McIntosh...	25	15-20	3.19	.....	1.03	1.23	.....
June 22	McIntosh...	25	20-25	6.06	.959	.979	.934	.....
June 29	McIntosh...	10	25-30	14.89	.403	.627	.....	.....
1915								
June 25	McIntosh...	10	.....	10.66	.....	.665	.....	0.811
	N. Spy.....	10	.....	7.38	.....	.845	.....	.992
	Fameuse...	10	.....	8.74	.....	.645	.....	.637
June 29	Baldwin...	10	.....	7.56	.782	.703	.632	.....
	R. Island...	10	.....	9.35	.784	.717	.641	.....
	N. Spy.....	10	.....	9.51	.981	.870	.771	.....
	Fameuse...	10	.....	8.62	.817	.725	.641	.....
June 30	McIntosh...	10	.....	9.73	.856	.893	.690	.....
	Baldwin...	10	.....	31.68	.197	.162	.133	.....
	R. Island...	10	.....	35.56	.154	.130	.126	.....
July 16	McIntosh...	10	.....	42.26	.244	.210	.163	.....
	Fameuse...	10	.....	29.62	.162	.247	.191	.....

It will be seen that the amount of water vapor given off by detached fruits does not vary so much with variety as with the size of the fruit; also, that the amount transpired per unit of green weight is not large, even in the very young fruit, and decreases as the fruit grows. While the above figures must not be taken as representing the rate of transpiration in fruits attached to the tree, yet it may be assumed that the same relation holds in the latter case. This is not surprising. When the apple is very small the

stomata are abundant on its surface. As the apple grows its surface area increases without a corresponding increase in the number of stomata. Lenticels and other openings in the skin may appear, but in a large apple the number of openings per unit of surface is greatly less than in the very young fruit.

TABLE III.—AMOUNT OF WATER TRANSPIRED FROM DETACHED APPLE LEAVES.

Date	Variety	Number of leaves	Water transpired; measured in grams per kilogram of green weight per hour		
			24 hrs.	48 hrs.	72 hrs.
1916			<i>Grams</i>	<i>Grams</i>	<i>Grams</i>
June 13.	Fameuse.	50	6. 85	7. 80	6. 49
	McIntosh.	50	7. 39	5. 61	5. 49
June 17.	McIntosh.	50	.....	5. 31	5. 05
June 22.	McIntosh.	50	8. 29	6. 68	5. 75
June 29.	McIntosh.	50	8. 83	8. 13	.....
1915					
June 30.	Northern Spy. . .	20	11. 82	9. 03	6. 65
	Fameuse.	20	11. 16	8. 63	7. 22
	McIntosh.	20	12. 81	9. 24	6. 50
July 14.	Baldwin.	20	8. 03	6. 87	6. 00
	Rhode Island. . .	20	8. 36	7. 30	5. 55
July 16.	McIntosh.	20	9. 19	7. 61	5. 63
	Fameuse.	20	10. 92	8. 59	5. 83

It will also be seen that the amount of water given off by detached leaves is much greater than that transpired by the fruits. Undoubtedly, this relation also holds true on the tree. It is an accepted fact of physiology that a plant's leaves are its chief organs of transpiration.

EXPERIMENTAL PRODUCTION OF LESIONS RESEMBLING THOSE OF DROUTH SPOT.

Chandler (5) employed a unique method to demonstrate the ability of the leaves to rob the fruit of water. Twigs bearing green fruits and leaves were detached from the tree, the cut ends of the twigs and the fruits were dipped in melted paraffin at a temperature low enough not to injure the tissue. These twigs were then placed in a cool, dark place where transpiration would not be excessive. It was found that the fruits wilted and shrunk inside the paraffin, while the leaves remained quite fresh.

It seemed that by employing this as a method of rapidly wilting the fruits it might be possible to produce lesions resembling those of drouth spot. A large number of tests of this sort were made in 1915 and 1916. The tests of 1915 were not so uniformly successful as those of 1916, since some time was spent in determining the proper relation of number and size of the leaves to the fruits to obtain best results. However, some success was met with in both seasons. It was found that with fruits up to 2.5 centimeters in diameter, a fruit spur bearing from one to three fruits (according to the number and size of its leaves) gave the best results.

In the beginning of the experiments the following checks were employed: (1) A twig with leaves removed and the cut ends of the twig and the fruits dipped in paraffin; (2) a twig with leaves and fruit attached, the cut end of the twig being paraffined; (3) detached fruits, with the ends of the stems paraffined. Since the fruits in the case of check 1 did not wilt, only checks 2 and 3 were employed in later experiments; and, finally, since the detached fruits did not wilt perceptibly during the period of the experiment, this check, also, was discontinued. In the case of check 2, leaves and fruit attached and the cut end of the twig paraffined, wilting of the fruits occurred, though perhaps not so rapidly as in the case of twigs with paraffined fruits. For some reason, lesions never developed on fruits from these check twigs. After being prepared the twigs were placed in a cool, dark place for a variable period, (from 12 to 24 hours) until they had wilted to a certain point which was learned by experience to yield the best results. The paraffin was then removed from the fruits, the ends of the twigs freshly cut and placed in water. Except in the case of large fruits it was always possible to bring the fruits back to their original state of turgor.

The lesions began to be apparent a short time after the removal of the paraffin, or as soon as the dead tissue became oxidized, but they showed most plainly after the fruits had again become turgid.

In 1916, 11 of these wilting experiments were made, involving in all 283 twigs and 449 fruits. Of these, 281 fruits developed lesions resembling those of drouth spot, and varying in type from superficial to deep seated; 168 fruits failed to show any injury whatever. The experiments were more uniformly successful with the smaller fruits. It was not attempted to conduct any experiments

with fruits larger than three and one-half centimeters in transverse diameter. The more rapid and severe the wilting the more the resulting injury resembled the deep-seated type of spot, such as was common in 1915. Less rapid and less severe wilting caused spots resembling the superficial type of lesion.

These spots of course resembled the early types of the disease since it was not possible to cause the fruits to grow subsequent to the injury. They bore the same relation to the vascular system of the fruit as in the case of natural injury. In a very few cases internal spots developed, with no external abnormality, thus resembling the cork more than the drouth spot. Plate IV is a photograph of some fruits in which the injury had been produced experimentally.

Histology of artificial lesions.—Microtome sections were made of some of the artificially produced spots, and these were studied in comparison with those from naturally diseased fruits. They were found to correspond with them in respect to the tissues affected, the relation of the dead spots to the vascular system, and in the nature of the injury to the cells. Figures 1 and 2 of Plate XII are drawings made from sections of artificially produced lesions. They should be compared with Plate V, fig. 2, and Plate VI, fig. 1.

ATTEMPT TO PREVENT DROUTH SPOT BY REMOVAL OF FOLIAGE.

It seemed possible that the reduction of the leaf surface of the tree during the critical period might operate to prevent the injury. A tree was selected in one of the "sick" parts of orchard No. 1 and on June 9, 1916, a number of its leaves were removed, reducing the total area of leaf surface by about one-third. The tree chosen was affected with die-back and had borne diseased apples in past years. At this date its crop was healthy, though one of the nearby trees bore diseased fruit. On June 20 twelve diseased fruits were found on this tree and on June 26 five more. These were removed and no disease developed subsequently. The remainder of the crop of this tree was healthy. On several of the surrounding trees the greater part of the crop was diseased, and on these trees also the disease developed rather late, a very few freshly diseased fruits being found as late as July 5. Too much must not be inferred from the result of this defoliation, as only one tree was involved, and it was possible to find several trees equally affected with die-

back in which no disease developed in 1916. In any event, reduction of the leaf surface of a tree could hardly be adopted as a control measure against drouth spot.

ATTEMPT TO CAUSE DROUTH SPOT BY OBSTRUCTING THE SAP FLOW.

It seemed possible that an obstruction to the sap flow might produce the disease. The writer has observed apples affected by the true fruit-pit, or stippen, on a branch partially girdled by a *Sphaeropsis* canker, the fruit on the other branches of the tree remaining healthy. On June 9, 1916, five branches were selected on five healthy trees in orchard No. 1, and notched deeply through the bark and outer sapwood on opposite sides, below the fruit-bearing portion. The disease did not develop on these branches or on any other branches of these trees.

CONCLUSION AS TO CAUSE.

These apple diseases must be considered of non-parasitic nature, and greatly influenced, if not caused, by lack of sufficient moisture. Brooks and Fisher (3) state that the corky pit or drouth spot of the Northwest is caused directly by drouth, and that the disease has been produced experimentally by subjecting Winesaps to sudden drouth. Allen (1) says: "much of the fruit-pit and winter-injury now so prevalent in the orchards [of the Hood River Valley] is due to drouth and improper fertilization."

The writer's observations of the cork and drouth spot of the Champlain Valley indicate an insufficient supply of water from the roots as one of the chief causal factors. Since, however, in a wet season, and under conditions where there seems to be no deficiency of moisture, these diseases may occur in trees that have been previously diseased; and since there is a tendency for certain trees to become diseased year after year, insufficient soil moisture cannot be looked upon as the sole cause. Some not thoroughly understood factor or factors must operate to produce the disease under these conditions.

Finally, it is suggested that the exact manner of occurrence of the injury may be by the leaves robbing the fruit of water during a critical period of low root supply and high transpiration. Rapid wilting of the fruits can be brought about by excessive transpiration from the leaves. It has been seen that this wilting may result

in the death of certain cells near the vascular bundles, forming lesions resembling those of drouth spot, and occasionally, of cork, Chandler (5) has presented evidence that transpiration from the leaves may bring about a scarcity of water in the fruit under field conditions. It is not impossible that this is at least one of the ways in which the disease may be caused.

This seems more likely than that the injury is due to an excessive transpiration from the fruit itself, or, as suggested by McAlpine for "crinkle," to the failure of the vascular network over large areas. The striking thing about these diseases is the presence, not the absence, of meshes of this vascular network in close proximity to the dead cell areas.

In making the above suggestion as to the cause of cork and drouth spot, the writer realizes that the small amount of experimental work done does not warrant a definite conclusion. There is, undoubtedly, much yet to be learned of the real nature of these diseases.

Further, it is not intended to advance this theory to explain the cause of true fruit-pit, or stippen, which occurs in a late stage of the fruit's growth and is said to develop in storage (McAlpine [12], [13], [15]).

CONTROL.

The most promising outlook for the control of drouth spot and cork seems to be in methods of conserving soil moisture and improving the water-holding capacity and physical condition of the soil. Clean cultivation, alone, is not effective. Perhaps clean cultivation combined with leguminous cover crops may accomplish more.

There seems to be a slight indication of the beneficial effect of a vetch-and-buckwheat cover crop in orchard No. 1 in 1916. A part of this orchard which had been badly affected with drouth spot in the past was practically free from it in 1916. This part of the orchard was clean-cultivated in 1915 and sowed to a cover crop of vetch and buckwheat. It is possible, also, that there are some indications in the case of the Stevens orchard at Orwell, Vermont, where a small area bearing sweet clover was continuously free from drouth spot, while clean-cultivated areas of the same soil type exhibited the disease. Also, in this orchard clean cultivation with seeding to alfalfa in 1915 was followed by an almost

complete absence of the disease in 1916. Too much must not be assumed from the latter circumstance in view of the rainy spring and the very inconsiderable amount of drouth spot throughout the Champlain valley that season. The chief reason for suggesting the use of leguminous cover crops lies in beneficial results reported from the Pacific Northwest. Allen (1) believes the "fruit-pit" and "winter injury" to be largely due to drouth conditions and improper fertilization, and says: "This statement appears to have been borne out during the past two years by the rapid disappearance of fruit-pit and winter injury following the application of irrigation and the use of leguminous crops in the orchards." Clawson (6) offers the use of a leguminous crop, preferably alfalfa, as a positive remedy for rosette in Washington orchards. It is claimed that two or three years' growing of alfalfa in an affected orchard results in the disappearance of the trouble.

The benefits derived from alfalfa are probably due to an improvement in the physical condition of the soil, resulting in a better water-holding capacity, and the addition of nitrogen. During the first two years alfalfa probably makes a large drain on the soil moisture, but it is a deep-rooted plant and after becoming established obtains its water largely from lower levels, and further acts beneficially by shading the soil. According to Clawson (6) the best method of alfalfa culture in the orchard would be a constant disking in of the alfalfa tops forming a vegetable mulch over the soil surface. The common practise with Washington growers is to cut two or three crops for hay and disk in the late growth the following spring. In some orchards the alfalfa has been grown continuously without harvesting, with good results. Clawson recommends that the alfalfa should not be planted before the orchard is five years old, and that it be then started in the centers of the rows, leaving, at first, a cultivated strip next to the trees. When the water supply is short it may even be advisable to plant the alfalfa in drills, allowing for cultivation between.

The conditions in the Champlain valley cannot be identical with those in the Northwest, for irrigation is not practised; but it seems possible that there may be some benefit obtained from the use of a leguminous cover crop or even continuous alfalfa culture in the orchard. Both these practises are being tried in two of the orchards which have been studied; a few years' observation will tell the result.

Cork, as occurring independently of drouth spot, has a tendency to be restricted to certain trees year after year. Some growers claim to have changed this habit of a tree for a period of years by very severe pruning. Perhaps in many cases the removal of certain "corky" trees would be advisable, since, usually in a well-cared-for orchard, the number of trees predisposed to cork is not large.

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EXPLANATION OF PLATES.

PLATE I.—CORK DISEASE OF APPLES.

Fig. 1. Surface and cross-section views of young Fameuse apples affected with cork. Fruits smooth externally. Photographed July 29, 1916. Natural size.

Fig. 2. Fameuse apples (nearly mature) affected with cork. The cut fruits show spots of cork scattered all through the flesh. The surface of the uncut fruit is covered with shallow depressions. Photographed September 6, 1916. Natural size.

PLATE II.—YOUNG APPLES AFFECTED WITH DROUTH SPOT.

Fig. 1. Superficial type of drouth spot. The fruit in the upper left hand corner has an older injury than the others and has shrunk somewhat. Hence, the extremely wrinkled appearance. Probably, this fruit, in cross section, would show a few brown spots in the flesh. The cross sections shown are of fruits similar to the three right-hand fruits in the top row. Note that the trouble is only skin deep. Three healthy fruits (in the center) are shown for comparison. Photographed June 19, 1916. Natural size.

Fig. 2. Young McIntosh fruits affected with drouth spot. The lesions are of the deep-seated type common in 1915. Photographed in June, 1915. Natural size.

PLATE III.—DROUTH SPOT OF APPLES.

Fig. 1. Cross sections of fruits similar to those shown in Plate II, fig. 2. Note the relation of the corky spots and cavities to the main vascular branches. The fruit in the upper right hand corner is healthy. Photographed in June, 1915. Natural size.

Fig. 2. Half-grown fruits affected with drouth spot. The fruit in the lower right hand corner shows deep-seated lesions as they appear on fruits of this size. The middle fruit in the lower row shows spots of the superficial type with wrinkles in the skin. The other fruits show the cracked and corky appearance of the skin which occurs when the fruit grows subsequent to drouth spot injury. Photographed in July, 1914. Natural size.

PLATE IV.—APPLES WITH ARTIFICIALLY PRODUCED LESIONS RESEMBLING DROUTH SPOT.

Variety, McIntosh. Photographed June 19, 1916. Natural size. Compare with Plate II and Plate III, fig. 1.

PLATE V.—PATHOLOGICAL HISTOLOGY OF CORK AND DROUTH SPOT.

Fig. 1. Drawing of an internal brown spot of cork. The dead cells are indicated by heavy stippling. The healthy cells are shown in outline only. Note the ladder-like arrangement of healthy cells next to the diseased area. Outlined with the aid of a camera lucida. $\times 50$.

Fig. 2. Cross section through a drouth spot of the superficial type with smooth surface. The dead cells in the hypodermal parenchyma are indicated by heavily stippled contents. Outlined with the aid of a camera lucida. $\times 215$.

PLATE VI.—PATHOLOGICAL HISTOLOGY OF DROUTH SPOT.

Fig. 1. Cross section through drouth spot on very young apple. Dead cells are distinguished by heavy stippling of the contents. In this case the disease affects the whole of the hypodermal parenchyma and in places extends into the cortex. Outlined with the aid of a camera lucida. $\times 100$.

Fig. 2. Cross section through a late stage of drouth spot, superficial type, showing layers of rectangular cells laid down preliminary to cutting off the dead area by means of a cork layer. One or two of the outer layers of rectangular cells have suberized

cell walls. Dead cells of the hypodermal parenchyma are shown by dark stippling of the contents. The epidermis has peeled off. Contents of healthy cells not shown. Outlined with the aid of a camera lucida. $\times 100$.

PLATE VII.—PATHOLOGICAL HISTOLOGY OF DROUTH SPOT.

Fig. 1. Cross section through superficial drouth spot showing wrinkles in the skin. Dead cells shown by dark stippling of the contents; contents of healthy cells not shown. Note that the dead areas occur in the hollows; also, their relation to the vascular system. Outlined with the aid of a camera lucida. $\times 67$.

Fig. 2. Cross section through a drouth spot in which the dead area is mostly in the tissue transitional between hypodermis and cortex. Note the relation of the vascular branches. Outlined with the aid of a camera lucida. $\times 67$.

PLATE VIII.—DROUTH DIE-BACK OF APPLE TWIGS.

Die-back twigs of the previous season with laterals from the base bearing clusters of dwarfed, linear lanceolate leaves. Photographed in July, 1915.

PLATE IX.—DROUTH DIE-BACK OF APPLE TWIGS.

Die-back twigs of the previous season being renewed by healthy laterals from the base. Photographed in July, 1915.

PLATE X.—DROUTH DIE-BACK OF APPLE TWIGS.

Fig. 1. A severely affected tree in orchard No. 1 with the diseased branches removed. This tree was dug up in June, 1915, for an examination of its roots which were found to be healthy. (See page 509). Photographed in June, 1915.

Fig. 2. Cross section through a die-back twig showing zone of parenchyma wood, *p*, between two layers of normal wood, *x x*. The brown discolored areas occupied by intercellular substance are indicated by dark shading. Outlined with the aid of a camera lucida. $\times 280$.

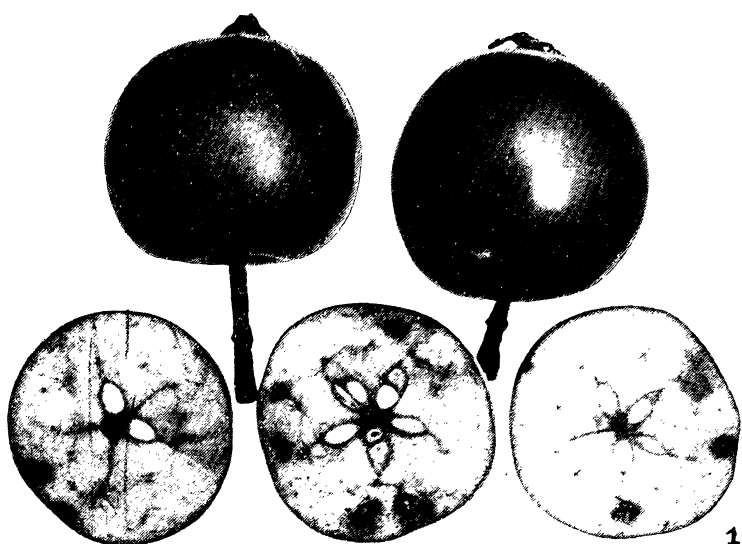
PLATE XI.—DROUTH DIE-BACK AND DROUTH ROSETTE OF APPLE TREES.

Affected trees in orchard No. 1. Photographed in July, 1916.

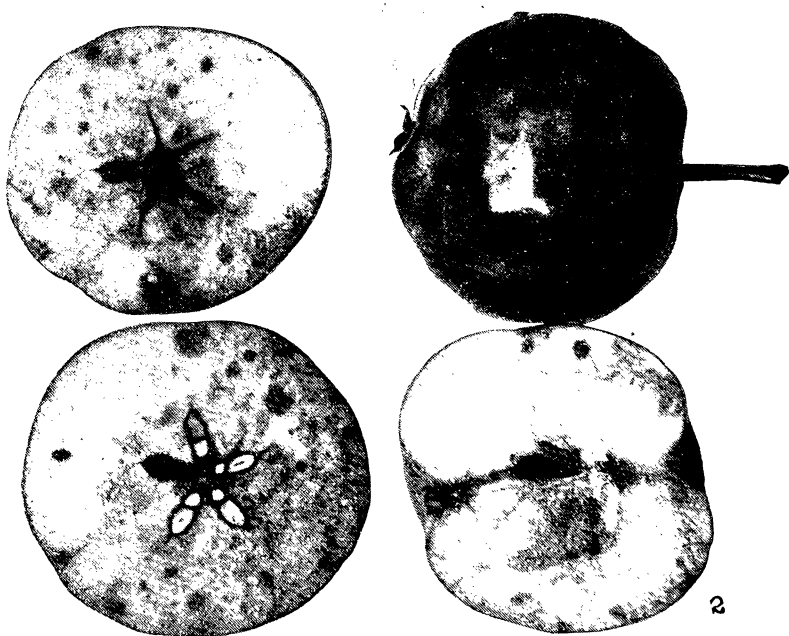
PLATE XII.—HISTOLOGY OF ARTIFICIALLY PRODUCED LESIONS ON APPLES.

Fig. 1. Cross section through an artificially produced lesion resembling drouth spot. Outlined with the aid of a camera lucida. $\times 215$. Compare with Plate V, fig. 2.

Fig. 2.—Cross section through an artificially produced lesion resembling drouth spot. Outlined with the aid of a camera lucida. $\times 100$. Compare with Plate VI, fig. 1.



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PLATE I.—CORK DISEASE OF APPLES.
(For explanation, see p. 521)

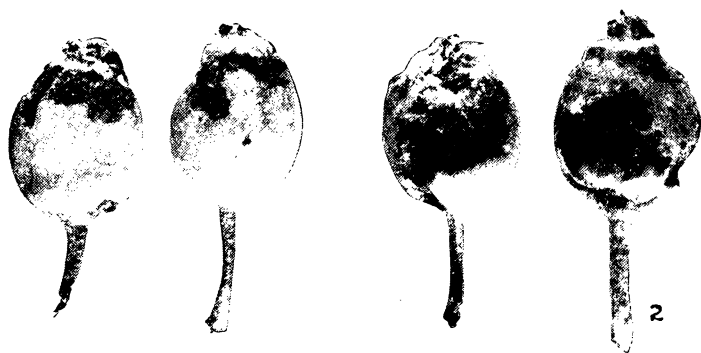
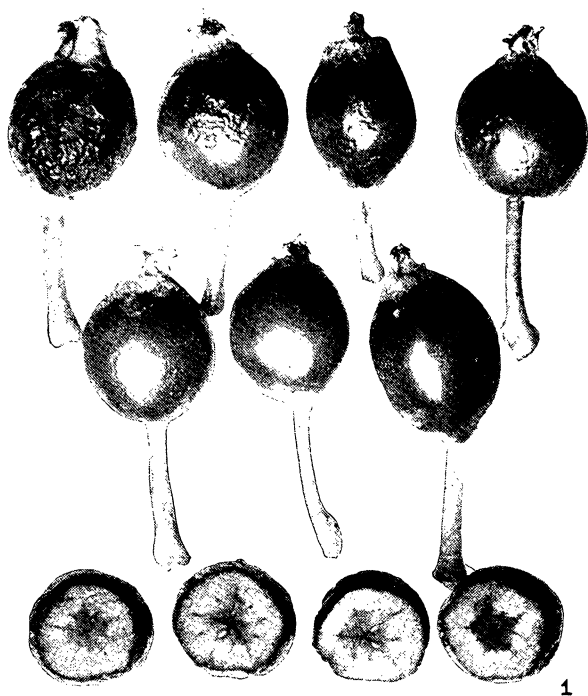
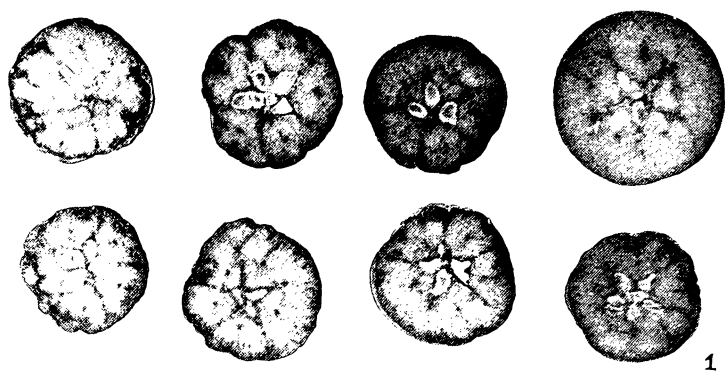
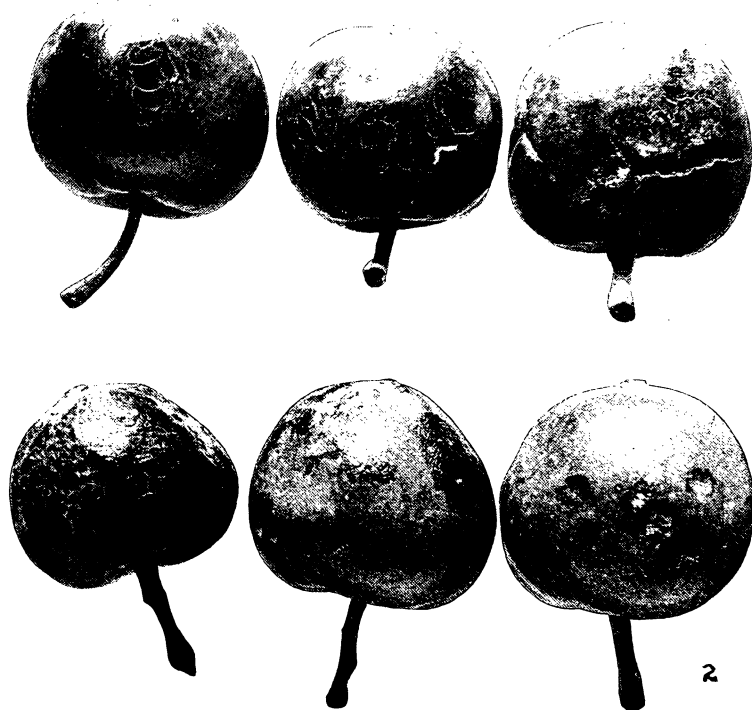


PLATE II.—YOUNG APPLES AFFECTED WITH DROUTH SPOT.
(For explanation, see p. 521.)



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PLATE III.—DROUTH SPOT OF APPLES.
 (For explanation, see p. 521.)

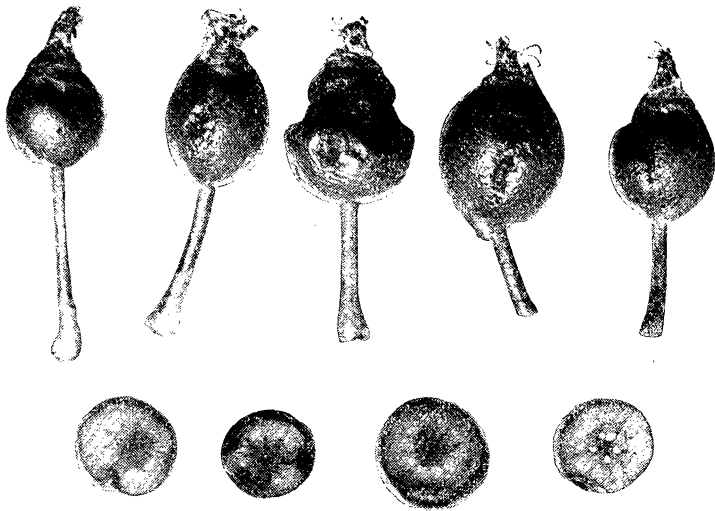


PLATE IV.—APPLES WITH ARTIFICIALLY PRODUCED LESIONS RESEMBLING
DROUTH SPOT.

(For explanation, see p. 521.)

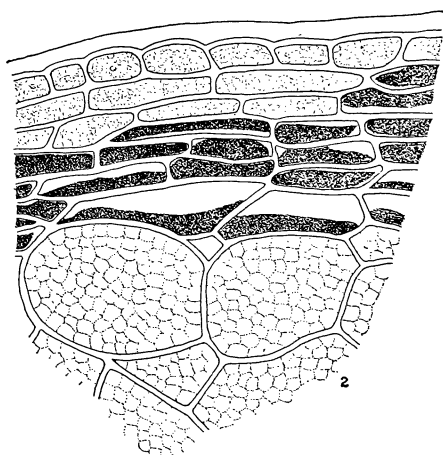
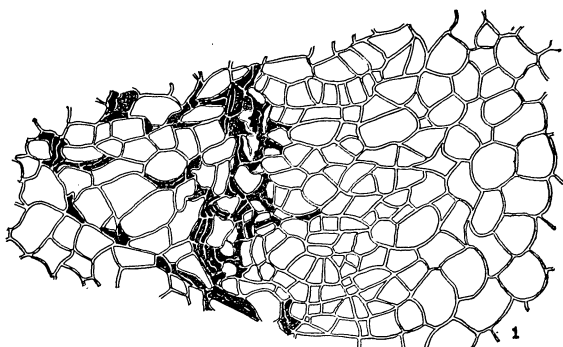


PLATE V.—PATHOLOGICAL HISTOLOGY OF CORK AND
DROUTH SPOT.
(For explanation, see p. 521.)

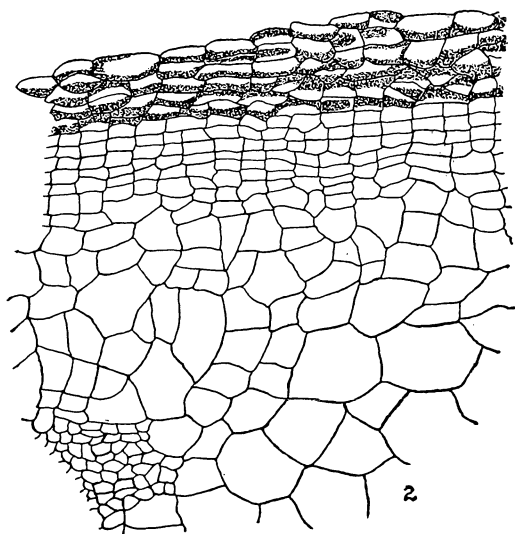
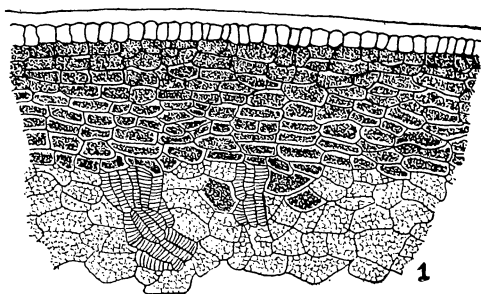


PLATE VI.—PATHOLOGICAL HISTOLOGY OF DROUTH
SPOT.

(For explanation, see p. 521.)

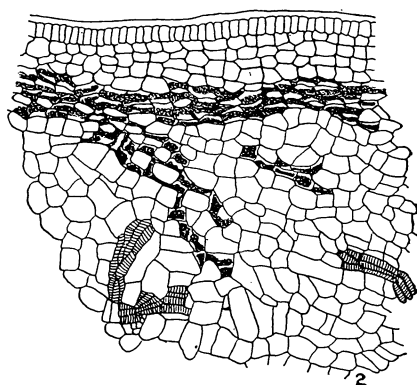
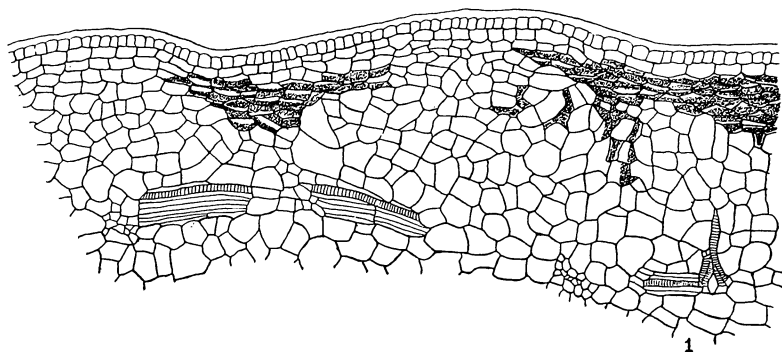


PLATE VII.—PATHOLOGICAL HISTOLOGY OF DROUTH SPOT.
(For explanation, see p. 522.)



PLATE VIII.—DROUTH DIE-BACK OF APPLE TWIGS.
(For explanation, see p. 522.)



PLATE IX.—DROUTH DIE-BACK OF APPLE TWIGS.
(For explanation, see p. 522.)

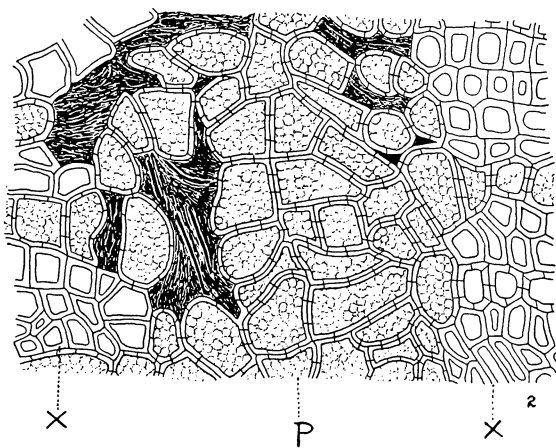


PLATE X.—DROUTH DIE-BACK OF APPLE TWIGS
(For explanation, see p. 522.)



PLATE XI.—DROUTH DIE-BACK AND DROUTH ROSETTE
OF APPLE TREES.
(For explanation, see p. 522.)

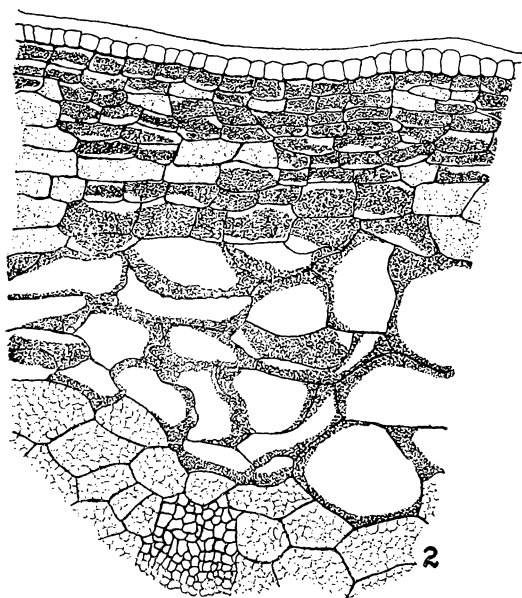
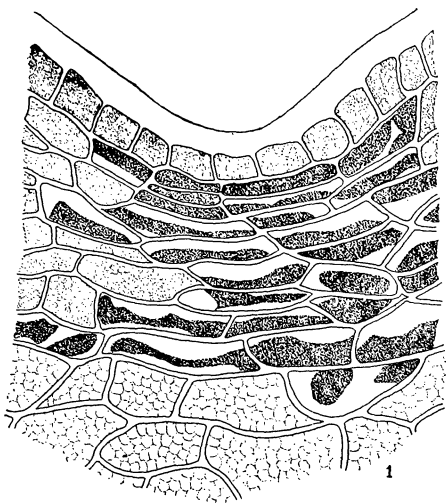


PLATE XII.—HISTOLOGY OF ARTIFICIALLY PRODUCED
 LESIONS ON APPLES.
 (For explanation, see p. 522.)